PB87-181178

COST ESTIMATION HANDBOOK FOR SMALL PLACER
MINES

U.S. Bureau of Mines
Spokane, WA

Mar 87

U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

NTIS®

REPORT DOCUMENTATION PAGE	1. REPORT NO. BuMines OFR 17-87	2.	PB87-181178

4. Title and Subtitle		5. Report Date
Cost Estimation Handbook for Small Placer Mines		Mar. 1987
		6.

7. Author(s) Scott A. Stebbins	8. Performing Organization Rept. No.

9. Performing Organization Name and Address	10. Project/Task/Work Unit No.
U.S. Bureau of Mines Western Field Operations Center 360 East Third Ave. Spokane, WA 99202	
	11. Contract(C) or Grant(G) No. (C) NA (G)

12. Sponsoring Organization Name and Address	13. Type of Report & Period Covered
Office of Assistant Director--Mineral Data Analysis Bureau of Mines U.S. Department of the Interior Washington, DC 20241	
	14.

15. Supplementary Notes

Approved for release Mar. 26, 1987.

16. Abstract (Limit: 200 words)

This report presents a method for estimating capital and operating costs associated with the exploration, mining, and processing of placer deposits. To ensure representative cost estimates, operational parameters for placer mining equipment and basic principles of placer mining techniques are detailed.

17. Document Analysis   a. Descriptors

b. Identifiers/Open-Ended Terms

Placer mining
Cost estimation

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report) Unclassified	21. No. of Pages 130
Release unlimited by NTIS.	20. Security Class (This Page) Unclassified	22. Price

FOREWORD

This report reflects the Bureau of Mines continued dedication to ensuring an adequate mineral resource supply. It provides information that will aid in the technical and economic evaluation of placer deposits by government evaluators and the private sector.

The "Cost Estimation Handbook for Small Placer Mines" represents an ongoing Bureau effort to provide detailed, reliable cost information. It is anticipated that such information will allow those charged with mineral resource evaluation to accurately determine the economic feasibility of specific deposits.

With this handbook, the Bureau targets the most active, yet most neglected segment of the industry: the small-scale, independent operation.

Pages 1, 2, and 3 are blank.

CONTENTS

5

CONTENTS--Continued

ILLUSTRATIONS

TABLES

UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

BCY	bank cubic yard	LCY/h	loose cubic yard per hour
d/a	day per year		
ft	foot	um	micron
ft^2	square foot	mi	mile
ft^2/yd^3	square foot per cubic yard	min	minute
		min/h	minute per hour
ft/h	foot per hour	sp gr	specific gravity
gpm	gallon per minute	ton	short ton
h	hour	ton/h	short ton per hour
h/shift	hour per shift	tr oz	troy ounce
hp	horsepower	tr oz/yd^3	troy ounce per cubic yard
in	inch		
kW	kilowatt	wt %	weight percent
kW/yd^3	kilowatt per cubic yard	yd/h	yard per hour
		yd^3	cubic yard
lb/LCY	pound per loose cubic yard	yd^3/d	cubic yard per day
		yd^3/ft^2	cubic yard per square foot
lb/yd	pound per yard		
lb/yd^3	pound per cubic yard	yd^3/h	cubic yard per hour
LCY	loose cubic yard	yr	year
LCY/a	loose cubic yard per year	o	degree
		%	percent

COST ESTIMATION HANDBOOK FOR SMALL PLACER MINES

By Scott A. Stebbins[1]

ABSTRACT

This Bureau of Mines publication presents a method for estimating capital and operating costs associated with the exploration, mining, and processing of placer deposits. To ensure representative cost estimates, operational parameters for placering equipment and basic principles of placer mining techniques are detailed.

INTRODUCTION

In 1974, the Bureau of Mines began a systematic assessment of U.S. mineral supplies under the Minerals Availability Program (MAP). To aid in this program, a technique was developed to estimate capital and operating costs associated with various mining methods. This technique, developed under contract to the Bureau by STRAAM Engineers, Inc., was completed in 1975, then updated in 1983. During the course of the update, it was noted that few provisions were made for estimating the costs of small-scale mining and milling methods typically associated with placer mining. The popularity and widespread use of placer mining methods indicated that a cost estimating system for placer mining would be of value to prospectors, miners, investors, and government evaluators.

This manual has been written to aid those involved with placer mining estimate the costs of recovering valuable minerals from placer deposits. It relies on the principle that cost estimates will be representative only if calculated for technically feasible mining operations. Since the design of such an operation can be difficult, provisions have been made to assist the user in achieving this goal.

Section 1 of the manual describes the processes involved in placering, and may be used to aid in designing a viable mine. Operational parameters for equipment commonly used in placer exploration, mining, and processing are discussed, as well as basic principles of successful placer mining technique. If the reader is unfamiliar with this form of mining, section 1 should be thoroughly understood prior to cost estimation.

---

[1]Mining Engineer, Western Field Operations Center, Bureau of Mines, Spokane, WA.

Section 2 contains a series of cost equations that enable the user to estimate capital and operating costs of specific placer techniques. Cost equations are designed to handle the wide variety of conditions commonly found in placer deposits. This allows the reader to tailor estimates to the characteristics of a particular deposit, which ensures representative costs. Although based primarily on gold placer operations, cost equations are valid for any other commodity found in deposits of unconsolidated material. Equations are geared to operations handling between 20 and 500 LCY/h of material (pay gravel plus overburden). Estimated costs are representative of operations in the western United States and Alaska, and are based on a cost date of January 1985.

This is not intended to be an exhaustive discussion of placer mining. Many detailed texts have been written on this process, any one of which will assist the reader in method design. A number of these are listed in the accompanying bibliographies.

ACKNOWLEDGMENTS

A special debt is owed to the late George D. Gale, metallurgist, Bureau of Mines. This handbook, and many of the ideas and facts it contains, are the product of his ingenuity.

10

SECTION 1

PLACER MINE DESIGN
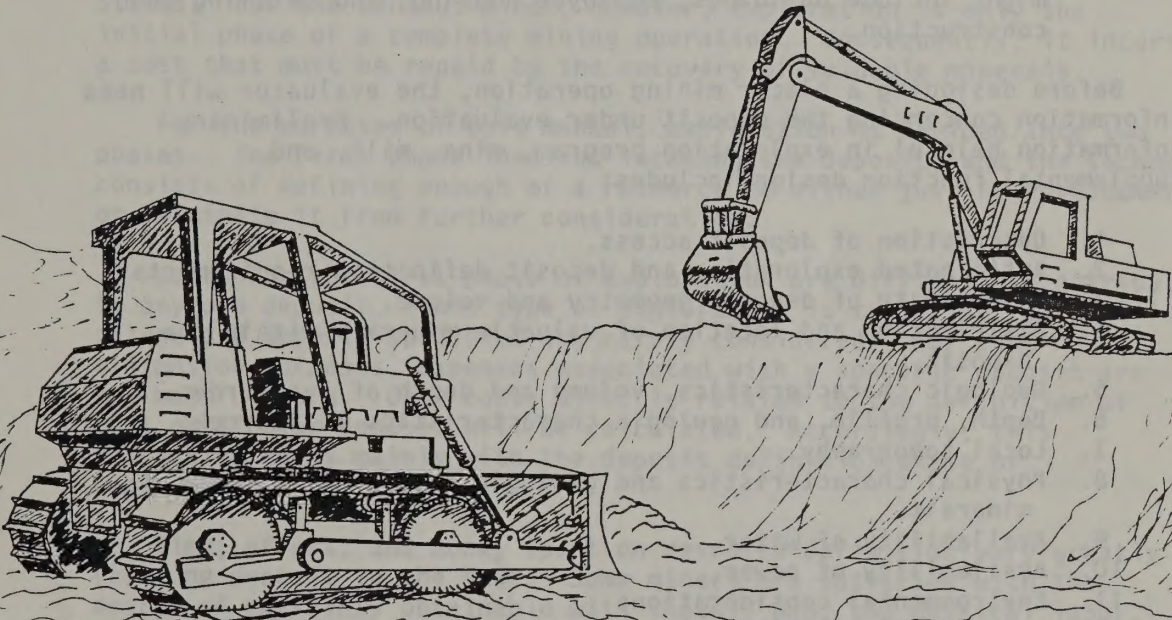
The complete design of a placer mine involves the integration of exploration, mining, processing, and supplemental systems for the efficient recovery of valuable minerals from an alluvial deposit. This design is the first step in accurate cost estimation.

In the first section of this handbook, individual systems are broken down as follows:

1. Exploration.--The phase of the operation in which resources are delineated. Since the amount of time and effort spent on discovery is difficult to tie to any one specific deposit, only the processes of delineation and definition are costed. Field reconnaissance, drilling, and panning are representative of items in this category.
2. Mining.--Deposit development, material excavation and transportation, and feeding of the mill are all included in this category. Items such as clearing and overburden removal are also listed here.
3. Processing.--Processing is defined as all tasks required to separate the desired mineral products from valueless material.
4. Supplemental.--Any item not directly related to mineral recovery, but necessary for the operation of the mine. These might include buildings, employee housing, and settling pond construction.

Before designing a placer mining operation, the evaluator will need information concerning the deposit under evaluation. Preliminary information helpful in exploration program, mine, mill, and supplemental function design includes:

1. Description of deposit access.
2. Anticipated exploration and deposit definition requirements.
3. An estimate of deposit geometry and volume.
4. Distribution and location of valuable minerals within the deposit.
5. Geologic characteristics, volume and depth of overburden.
6. Depth, profile, and geologic characteristics of bedrock.
7. Local topography.
8. Physical characteristics and geologic nature of valuable minerals.
9. Availability of water.
10. Availability of power.
11. Environmental considerations.
12. Labor availability and local wage scales.
13. Housing or camp requirements.

Information should be as detailed as possible. By providing such items as exact haul distances and gradients, accurate estimates of overburden thickness and deposit area, the evaluator will increase the precision of cost calculations.

With the above information in hand and the help of the material contained in the following pages, the user will be able to design a technically feasible operation. The following sections will assist the evaluator in planning each phase of the mine. When designing systems for individual areas of operation, the evaluator must keep in mind that these systems will interact and must be compatible. For instance, hourly capacity of pay gravel excavation should equal mill feed rate, and the mill must be set up to easily accept gravel from the equipment used for material transportation.

Most of the information contained in the following pages is based on average operating parameters and performance figures for the various types of equipment used in placer mining. Figures and conclusions derived from this manual must be considered estimates only. Because of the many variables peculiar to individual deposits, the stated levels of equipment performance and costs may not be realized on any given job.

EXPLORATION

It can be safely stated that far more people seek placer deposits than actually mine them. Exploration for placer gold can be enjoyable work and has achieved a recreational status in the western United States. For the serious miner, however, exploration is only the initial phase of a complete mining operation. Consequently, it incurs a cost that must be repaid by the recovery of valuable minerals.

For the purposes of this manual, exploration is divided into two phases. The first phase involves locating the deposit, and the second consists of defining enough of a resource to either justify development, or eliminate it from further consideration.

Costs for the first phase of exploration are difficult to attribute to any one deposit. This type of exploration is typically regional in nature and deposit specifics are rarely considered. For cost estimation purposes, expenses associated with a specific deposit are the main concern. Only costs directly related to the definition of that particular deposit will be calculated. Accordingly, this discussion deals mainly with the deposit definition phase of exploration.

Time, effort, and money spent on resource definition vary greatly from one deposit to the next. Some miners are satisfied with the degree of certainty obtainable with shovel, pan, and physical labor. Others, wishing more security, systematically trench or drill the deposit and process samples using some sort of mechanical concentrator. Still others, hoping for greater assurance, follow up drilling or trenching by bulk sampling using machinery intended for mining. These samples are then processed in a scaled-down version of the proposed mill. The extent of effort spent on deposit definition is related to:

1. Degree of certainty desired.
2. Availability of capital.
3. Experience (or lack of experience) of the operator.
4. Historical continuity of similar or local deposits.

It is intuitively obvious that the degree of certainty of success is related to the extent of exploration undertaken, and it is desirable to delineate the deposit as extensively as is practical prior to production. In many cases, however, lack of exploration capital and the need for cash flow limit the exploration phase, and mining commences on the limited information at hand. Goals of a thorough exploration program include determination of:

1. Deposit volume.
2. Deposit and overburden geometry.
3. Deposit grade.
4. Distribution of valuable minerals within the deposit.
5. Geological and physical characteristics of the valuable minerals.
6. Geological and physical characteristics of waste material.
7. Location, geology, and physical nature of the bedrock.
8. Water availability.
9. Environmental concerns.

By comparing the above list with the one on page 16, it can be seen that much of the information needed to estimate costs of developing and operating a placer mine can be gathered during deposit exploration. Consequently, costs estimated after exploration are much more precise than estimates made prior to exploration.

In the costing section of this manual, two methods are presented for estimating exploration costs. With the first, a cost can be calculated by simply estimating the total resource of the deposit. This method is based on total exploration expenditures for several active placer operations, but is not considered as precise as the second method.

The second method requires that the evaluator design an exploration plan. This plan should include the type and extent of each exploration method required. For example:

1. 5 days of general reconnaissance with a 2-man crew.
2. 10,000 linear ft of seismic surveying.
3. 4,000 ft of churn drilling.
4. 1,000 yd^3 of trenching.
5. 2,000 samples panned.
6. Camp facilities for four people for 20 days.

To aid in developing this plan, some techniques commonly employed for sampling and subsurface testing of placer deposits are discussed in the following paragraphs. These include panning, churn drilling, bucket drilling, rotary drilling, trenching, and seismic surveying.

Panning

One of the most versatile and common sampling devices in placer mining is the gold pan. It is used as a reconnaissance tool, a sampling tool, and a concentrate refining tool. With a gold pan, the prospector has the ability to, in effect, conduct his assay work on- site with immediate results. Although accuracy may be poor, the prospector can determine in the field if gold is present and in roughly what amounts.

The gold pan uses gravity separation to concentrate heavy minerals. Pans come in a variety of sizes, ranging in diameter from 12 to 16 in. An experienced panner can concentrate approximately 1/2 yd^3 gravel daily. Because of this limited capacity, panning can be costly when large volumes must be processed; however, low capital expense, ease of use, versatilty, and portability make the gold pan invaluable.

Immediate feedback when exploring or mining is a prime advantage of the gold pan. This one feature is extremely important for eliminating areas of low potential during exploration, and for separating pay gravel from waste during production. Skilled use of a gold pan during the mining sequence can make or break the small mining operation.

Churn Drilling

Methods of drilling placer deposits are quite varied, but the most common technique is churn drilling. Typically, the churn drill uses percussion to drive casing down through the material being sampled. (In some instances, casing is not used.) After a length of casing is driven, the contents are recovered (bailed), another length of casing is added, and the process is repeated. Depths are usually restricted to less than 150 ft, and hole diameters range from 4 to 10 in.

One advantage of this method is that sample processing keeps pace with drilling, allowing good control of drill hole depth and instantaneous logging. A churn drill is generally operated by two people; the driller operates the drill, bails the sample, and keeps track of the depth of each run; the panner estimates the volume of the samples, pans them as they are recovered, and logs the hole.

Drilling rates average about 2 ft/h but can reach as much as 4 ft/h in good ground. Highest penetration rates are achieved in clay, soil, sand, pebbles, cobbles, and soft bedrock. The machine is suitable for drilling through cemented gravels and permafrost, although productivity will diminish. Penetration is drastically reduced in ground containing boulders and in competent or hard bedrock.

Samples recovered from churn drill casings are often subject to
volume changes caused by compaction or expansion of material within the
casing. Sample volume changes can also be caused by compaction around
the bit forcing material out into the surrounding formation, and by
material "run-in" due to high deposit water content. One or more of
these conditions may be encountered in any one deposit, requiring the
application of volume corrections. This task is often difficult and
requires the experience of a qualified driller or engineer.

Bucket Drilling

Bucket drilling, although not as popular as churn drilling, has
important applications in placer deposit evaluation. Under ideal
conditions, this technique is relatively fast and provides large
samples. In this system, a standard rotary drill is equipped with a
special "bucket" bit consisting of a 30- to 48-in-diam cylinder, 3 to 4
ft long. The bit is driven down through the deposit using the
rotational force of the drill until the cylinder is full. As the bit
is withdrawn, a mechanism closes off the bottom of the bit retaining
the sample. The process is then repeated until the desired depth is
reached.

Bucket drills perform best in sands, soils, pebbles, and clays.
Progess is slow, and sometimes impossible, in ground containing
boulders, cemented gravel layers, and bedrock. The size of the bit
tends to disperse drilling force over a large area, thereby reducing
the effective penetration rate. For this reason the bucket drill
quickly becomes inefficient in hard or compact material. Problems are
also encountered in saturated ground, where dilution often occurs.

Bucket drilling extracts a much larger sample than other drilling
methods. Consequently, the influence of compaction and expansion of
material within the bit is reduced.

Rotary Drilling

This type of drill, commonly used for drilling large diameter
blastholes in surface mining, has found limited use in placer
exploration. The only way to obtain a sample with this machine is to
analyze drill cuttings. Since the method does not provide a core, it
is difficult to associate a volume with the recovered material, and it
is hard to estimate the depth horizon of the sample.

Rotary drills are useful in that they provide a fast, inexpensive
way to determine the depth of bedrock. Holes provided by rotary drills
range from 6 to 15 in. in diameter and reach any depth required for
placer mining. Virtually any material can be drilled, and penetration
rates are far superior to any other placer drilling method. Regardless
of the steps taken, however, it is difficult to accurately estimate
deposit grade with samples obtained from rotary drilling.

Trenching

In fairly shallow dry deposits, trenching with a backhoe is an extremely effective sampling technique. The procedure involves digging a trench to bedrock, then obtaining material from a channel taken down one side of the trench. This material is then measured and analyzed, providing a grade estimate. Another method relates an assay analysis of all the material extracted by the backhoe to the volume of the trench. The disadvantage of this method is the inability to determine the horizon of valuable mineral concentration. With either case, large volume samples are available at a low cost.

In sampling situations, backhoes can excavate from 20 to 45 LCY/h. Sample control is typically good with little volume distortion or material dilution under properly controlled circumstances. Backhoes are relatively inexpensive, easy to operate, versatile, and readily available. The machine can dig a variety of formations, and depths up to 30 ft below the machine platform are possible. In saturated ground, keeping the trench open for sampling is normally a major problem.

Seismic Surveys

In placer mining, bedrock depth plays a key role. Although not always the case, gold tends to concentrate near, on, or even in bedrock in a majority of placer deposits. Consequently, it is imperative to understand the nature of the bedrock and to design a mining method and select equipment based on its depth.

One method of determining bedrock depth is seismic refraction or reflection. In simple terms, the technique involves bouncing sound energy off the relatively resistant bedrock to determine its depth. The method is much cheaper than drilling a series of holes and, if bedrock proves to be too deep for practical mining, may prevent unnecessary drilling.

MINING

Next, a method for excavation and transportation of material contained in the deposit is needed. Mining methods are typically dictated by several basic factors. Deposit depth, size, and topography are of primary importance. The geologic nature of the deposit and accompanying overburden both play key roles. Types of equipment obtainable locally, sources of power, and the availability of water are all important factors. In some cases, operators may simply feel more confident using one method of extraction as opposed to another, even if local conditions are unfavorable.

In any event, the mining method should be designed with one fundamental goal in mind: To extract pay gravel from the deposit and move it to the mill at the lowest possible overall cost. Several basic concepts should be designed into the mining method to keep costs low. These include:

1. Haul only pay gravel to the mill. Eliminate hauling and processing unprofitable material.
2. Handle both overburden and pay gravel as few times as possible. Do not pile overburden or tails on ground that is scheduled for excavation.
3. Locate the mill at a site that minimizes average pay gravel haul distance. In most instances, it is cheaper to pump water than to haul gravel.
4. Do not mine gravel that is not profitable even if it contains gold. Money is lost for every yard of gravel mined if that gravel does not contain enough value to pay for the cost of mining and processing.

As can be seen, common sense plays a large role in the proper design of a placer mine. The same holds true for mine equipment selection. Countless combinations of equipment have been tried in attempts to effectively mine placer deposits. Equipment typically used in the western United States includes:

1. Backhoes (hydraulic excavators).
2. Bulldozers.
3. Draglines.
4. Dredges.
5. Front-end loaders.
6. Rear-dump trucks.
7. Scrapers.

Each type of equipment is suited to a particular task. In some instances, only one piece of equipment may be used to remove overburden, excavate and haul pay gravel, and place mill tailings and oversize (i.e., bulldozers). More often, several different types of equipment are utilized to take advantage of their specific attributes.

18

When selecting placer mining equipment, the evaluator must consider two important concepts. First, the volume of earth in place is less than the volume of the same earth after excavation. This point is critical in cost estimation and must be remembered. Since placer gravel is relatively light, placer mining equipment is typically limited by volume capacity, not weight capacity. For this reason, mine equipment capacities and associated cost equations in this handbook are based on volume after accounting for material swell--in LCY. Resource estimates are typically stated in BCY--the volume before accounting for material swell. This has a significant meaning to the design of a placer mining system. To mine a 500,000 BCY deposit, equipment will have to move 570,000 LCY of gravel if the material swells 14% (typical for gravel deposits). Although the total weight of material moved is constant, equipment will have to move a larger volume of gravel than the "in place" estimate indicates. As a result, the mining system should be designed around the total LCY of gravel to be moved, not the total BCY.

Second, mine equipment equations in the costing section are based on the maximum amount of overburden, pay gravel, and mill tails moved daily. Although average volume handled might be less, equipment must be selected to handle the maximum load.

To aid in mine planning, and to obtain reasonable capital and operating mine costs, the following will typically be required:

1. Total length and average width of haul and access roads.
2. Total surface area of deposit.
3. Nature of ground cover.
4. Topography of deposit area.
5. Total LCY of overburden, and maximum amount of overburden handled daily.
6. Total LCY of pay gravel, and maximum amount of pay gravel handled daily.
7. Total cubic yards of mill tails handled daily.
8. Type of equipment desired
9. Average haul distances and gradients for overburden, pay gravel, and tailings.

The following is a discussion of the principal types of equipment used in excavating and hauling overburden, placer gravel, and mill oversize and tails, and may be used to aid in mine design and equipment selection.

Backhoes (Hydraulic Excavators)

The backhoe is one of the most efficient types of equipment for bedrock cleanup. It is most often used for the extraction of pay gravel, but can also be used for excavation of overburden. The machine has almost no capacity for transportation of material and for that reason is used in conjunction with either front-end loaders, trucks, or in some cases, bulldozers. Depending on bucket selection, the machine can handle a variety of ground conditions including clays, poorly sorted gravels, tree roots, and vegetation. Digging depths of over 30 ft are obtainable with certain backhoes, but production capability decreases rapidly as maximum digging depth is approached. This problem can be avoided by excavating working platforms at various depths below the original surface.

Backhoes typically used in the western United States are capable of excavating from 95 to 475 LCY/h. Sizes range from 105-hp machines with 0.50-yd^3 buckets to 325-hp units with 3.75-yd^3 buckets. Capacity is contingent upon digging difficulty, operator ability, swing angle, digging depth, and obstructions.

The backhoe is ideal for situations where bedrock cleanup is critical, obstructions exist in the mining area, and other means of transporting gravel are available.

Bulldozers

The bulldozer represents an extremely versatile tool in placer deposit extraction, and is the most popular. It can be used for overburden removal, pay gravel excavation, bedrock cleanup, overburden and pay gravel transportation, road construction, tailings placement, and a variety of minor functions. The bulldozer is the only device capable of handling all tasks required for placer mining in a practical manner and must be considered if capital is scarce.

Although bulldozers can handle all placer mining functions, they are not necessarily the most efficient machine for any one task. With its ripping capacity, the bulldozer is capable of cleaning up bedrock; however, the backhoe is much more selective and efficient. The bulldozer can, and often is, used to transport gravel, but in most cases trucks, scrapers, and front-end loaders can each do the job cheaper if haul distances are more than a few hundred feet. In addition, bulldozers are not well suited to move large volumes of gravel or to dig to excessive depths. In both instances, draglines exhibit superior performance.

A major advantage of the bulldozer is its ability to excavate, transport, and load the mill all in one cycle, eliminating the need for expensive rehandling. Dozer capacities for excavating and hauling range from 19 LCY/h for a 65-hp machine up to 497.5 LCY/h for a 700-hp dozer (based on a 300-ft haul distance). Capacity is dependent upon ripping requirements, operator ability, cutting distance, haul distance, digging difficulty, and haul gradient.

20

Dozers are best suited for situations where deposit and overburden thicknesses are not excessive, few large obstructions are present, and haul distances average less than 500 ft.

Draglines

Draglines are well suited for excavating large quantities of overburden, gravel, and waste. Although their material transporting ability is limited, draglines with booms up to 70 ft long are capable of acting as the sole piece of mining equipment. As with the bulldozer, draglines can excavate overburden and pay gravel, load the mill, and remove tailings; however, draglines are relatively inefficient at bedrock cleanup, and do not handle difficult digging as well as backhoes or dozers.

Depths of over 200 ft are obtainable with this type of machine, and when used in conjunction with front-end loaders or rear-dump trucks, large capacity operations are possible. Draglines handle from 28 LCY/h for a 84-hp unit to 264 LCY/h for a 540-hp machine. Capacity is dependent upon bucket efficiency, swing angle, and operator ability.

Draglines are ideal for overburden removal and for large, deep deposits where bedrock cleanup is not critical. They must, however, be matched with the right equipment (i.e., portable mills or gravel transportation machinery).

Dredges

Cost estimation equations for dredging are not included in this handbook. Dredges, except for recreational units and small machines used in active channels, are designed for high capacity excavation of specific placer environments. The machines are best utilized in large volume, relatively flat-lying deposits that occur below water level. Due to large capital investment requirements and a scarcity of ground suitable for large-scale dredging, they are uncommon in the western United States.

Operating costs for large capacity dredges average approximately $0.70/yd³. Purchase and refurbishing costs are often more than $3 million, and can run over $10 million. In large volume situations, dredges must be considered. Since suitable applications are rare, however, they have not been included in this manual.

21

Front-End Loaders

This versatile machine is capable of many functions. In the western United States, its primary use is hauling previously excavated gravels, and the subsequent loading of the mill. Although front-end loaders are not the most efficient hauling unit, their self-loading ability provides many advantages. One is the elimination of the need to match the excavation machine with the haul unit. With a front-end loader, the excavator can operate at its own pace and simply stockpile material. The loader then feeds from the stockpile and transports gravel to the mill feed hopper. This removes the problem of matching excavator output with truck cycles or mill feed rates.

The machine is also capable of removing and transporting mill oversize and tailings; however, front-end loaders are not particularly adept at excavating consolidated material. If overburden or gravel are at all compacted, a backhoe or bulldozer should be used for primary excavation.

Front-end loaders are capable of hauling from 24 LCY/h for a 65 hp, 1-yd^3 machine to 348 LCY/h for a 690 hp, 12-yd^3 machine (based on a 500 ft haul distance). Capacity varies with haul length, haul gradient, operator ability, bucket efficiency, and type of loader.

Front-end loaders are best utilized as haul units over distances of less than 1,000 ft. Their versatility makes them useful for pay gravel and overburden transportation, mill oversize and tailings removal, and general site cleanup.

Rear-Dump Trucks

Trucks represent the least expensive method of material movement over long distances; however, since other machinery is required for loading, total gravel transportation expenses over short distances may be higher than for front end-loaders or scrapers. Trucks generally serve two purposes: Material movement and mill feed. They have relatively low capital costs and require little maintenance compared to other placer equipment. Trucks do need fairly good road surfaces and require careful matching with loading equipment to achieve acceptable efficiency.

Capacities for units at small placer operations range from 3 to 47.5 yd^3. Trucks are most productive over haul distances of 1,000 to 10,000 ft and can travel faster than equivalent-sized scrapers or front-end loaders. Production capacities range from 32.3 LCY/h for a 3-yd^3 truck to 444.8 LCY/h for a 47.5-yd^3 truck (based on a 2,500 ft haul distance). Capacity is contingent upon loader capacity, haul distance, and haul gradient.

Trucks are suited to operations where a fixed mill is situated more than 1/2 mi from the minesite. They are equally effective hauling pay gravel, overburden, or mill tailings and oversize, but must be accompanied by a method of material loading.

Scrapers

These machines are noted for their high productivity when used to transport overburden, pay gravel, and tailings. As with front-end loaders, scrapers are self-loading, although bulldozers or other scrapers often assist. They are capable of much higher speeds and greater capacity than front-end loaders, and exhibit haulage characteristics similar to rear-dump trucks. Scrapers, however, are more costly to purchase and maintain.

Scrapers are limited in their ability to excavate consolidated or unsorted material. A bulldozer equipped with a ripper must precede them in overburden or gravel that is not easily drifted. If boulders are present, they must either be blasted or removed by other means. The nature of the scraper-dumping mechanism renders them unsuitable for direct mill feed. When used to haul pay gravel, scrapers will typically unload near the mill, and bulldozers will then be used to feed material.

Capacities range from 201 LCY/h for a 330-hp machine to 420 LCY/h for a 550-hp machine (based on a 1,000 ft haul distance). Capacity is contingent upon haul distance and gradient, and loading procedure.

In placer mining, scrapers are best utilized for transportation of unconsolidated overburden or mill tailings over distances ranging from 500 to 5,000 ft.

PROCESSING

Often the most difficult part of placer mining is achieving the desired recovery of valuable minerals from mine-run gravel. The design of a successful mill is a specialized science and often proves difficult even for those actively involved in placer mining. Great care must be taken to ensure the recovery of a high percentage of contained valuable minerals. Obviously, the profitability of an operation is directly related to the percentage of contained valuable minerals recovered by the mill.

Although mill design can be difficult, the basic premise used in heavy mineral recovery is quite logical. In placer deposits, high density minerals have been concentrated by combinations of natural phenomenon such as gravity, turbulent fluid flow, and differences in mineral density. Consequently, it would seem practical to utilize these conditions to further concentrate heavy minerals. This form of mineral recovery is referred to as gravity separation and is the basis for most placer mills.

Gravity processes must consider both particle specific gravity and
size for effective separation. Differences in specific gravity alone
will not distinguish various materials. It is the differences in
weights in a common medium that creates efficient separation.
Consequently, a particle of high specific gravity and small size may
react the same as a large particle with low specific gravity in a given
fluid. If gravity separation is to be effective, size control must be
implemented to take advantage of differences in particle specific
gravity.

Equipment used for gravity separation ranges from gold pans to
pre-built self-contained placer plants. In general, the most widely
employed devices in the western United States are:

1. Jig concentrators.
2. Sluices.
3. Spiral concentrators.
4. Table concentrators.
5. Trommels.
6. Vibrating screens.

In reference to the above list, trommels and vibrating screens are
used for particle size classification, and the remainder are forms of
gravity concentrators. In addition, feed hoppers and conveyors are
needed for surge capacity and material transportation. These items,
which are commonly neglected in plant costing, must be carefully
selected to ensure proper plant operation.

Although the complete design of a placer recovery plant cannot be
thoroughly covered in the space available here, several sample flow
sheets illustrating basic placer mill design are included at the end of
this section. Along with a flow sheet detailing equipment type, size,
and capacity required for the mill, the following will be needed to
obtain an accurate cost estimate using this manual:

1. Maximum feed capacity of the mill.
2. A material balance illustrating feed, concentrate, and tailings
     rates.
3. The purpose of each gravity separation device (rougher, cleaner,
     scavenger, etc.).
5. Method of removal and transportation of mill tails and oversize.

The following discussion details equipment used in gravity
separation and may prove useful in mill design.

Conveyors

As material travels through a mill circuit, it can be moved by conveyor, pumped in a slurry, or transferred by gravity. In placer processing mills, material is most often transported in a slurry or by gravity. In some cases, however, conveyors are necessary. Conveyors are typically used for situations of extended transport where material need not be kept in a slurry--such as the removal of oversize or tailings. They provide an inexpensive method of transporting large quantities of material over fixed distances. In the case of placer processing plants, this distance typically ranges between 10 and 120 ft. Conveyors used in these plants are typically portable, and consequently come complete with framework and support system ready to operate.

Conveyor capacity is related to belt width, belt speed, and material density. For most placer gravels, capacities range between 96 yd^3/h for an 18- in-wide belt to 480 yd^3/h for a 36-in-wide belt.

Feed Hoppers

The initial piece of equipment in most mill circuits is a feed hopper. The hopper is used in conjunction with a feeder to smooth out material flow surges introduced by loading devices with fixed bucket sizes (front-end loaders, rear-dump trucks, etc.). Hoppers often contain a grizzly in order to reject large oversize material. The feeder, typically a vibrating tray located under the hopper, transfers gravel at an even rate to the circuit. Although the hopper-feeder combination may appear to be a minor piece of equipment, a steady flow of material through the mill is very important for effective gravity separation.

Hopper capacity and feeder capacity are two separate items. Generally, hoppers are designed to hold enough material to provide a steady flow of gravel despite surges inherent in mining cycles. Feeders are set to provide the appropriate flow rate to the mill. So even though a hopper may have a 100 yd^3 capacity, the feeder might provide material at 20 yd^3/h.

Feeders are not always used in placer mills. In such cases, feed rate is regulated by the size of the opening in the bottom of the hopper. The cost estimation curves in this manual calculate hopper/feeder costs based on feeder capacity, which typically equals mill capacity. Factors are provided for situations where feeders are not used.

25

Jig Concentrators

Jigs are gravity separation devices that use hindered settling to extract heavy minerals from feed material. They typically consist of shallow, perforated trays through which water pulsates in a vertical motion. In most instances, a bed made up of sized-shot, steel punchings, or other "ragging" material is placed over the perforations to promote directional currents required for separation. Slurried feed flowing over the bed is subjected to the vertical pulsations of water which tend to keep lighter particles in suspension while drawing down heavier constituents. These heavy minerals are either drawn through the bed and discharged from spigots under the jig or, if too large to pass through the perforations, are drawn off near the end of the machine. Lighter particles continue across and over the end of the jig as tailings.

Jigs are sensitive to feed sizing. They are generally utilized for feeds ranging from 75 microns to a maximum of 1 in, but recoveries improve if feed is well sized and kept to minus 1/4 in. Efficiency is maximized when feed materials have been deslimed and sized into a number of separate fractions for individual treatment. Optimum solids content for jig plant feed ranges from 35 to .50%--the object being to avoid excessive dilation of the material. Capacities for jigs range from 0.1 to 400 yd^3/h and are dependent upon desired product as well as equipment size.

Sluices

The most common gravity separation device used in placer mills, sluices are simple to construct, yet effective heavy mineral recovery tools. Sluice construction is quite diverse and opinions differ widely with respect to capacity, riffle design, and recovery. In general, capacities and performances vary with box width and slope, gold particle size, nature of feed, and availability of water.

Sluices are primarily used for rough concentration and are capable of processing poorly sorted feeds. As with other methods, however, recovery is related to the degree of previous sizing.

Sluice design can be quite complex but usually is a matter of trial and error. Several basic principles typically apply. Width is determined by the maximum and minimum volume of water available, the size and quantity of oversize feed that must be transported, and the slope. Length depends principally on the character of the gold. Coarse and granular gold settles quickly and is easily held in the riffles, while fine gold and porous gold may be carried some distance by the current. Velocity of the water is controlled primarily by the slope. In general, the sluice should be constructed and installed so that water flowing through the box will transport oversized material and prevent sand from packing the riffles.

26

If the surface of the water flowing through the sluice is smooth, the bottom of the sluice is probably packed with sand, allowing little gold to be saved. The desired condition occurs when waves form on the surface of the water flowing through the sluice, and these waves, along with the wave-forming ridges of material on the bottom of the sluice, migrate upstream. This indicates an eddying or boiling activity on the lee side of the ridges which maximizes gold recovery and tailings transport. Consequently, the sluice attains maximum efficiency when riffle overloading is incipient.

Sluices are generally considered to be high capacity units, with a 12-in-wide sluice box capable of handling 15 yd^3/h if sufficient water is available. A 24-in sluice can handle up to 40 yd^3/h, and 48-in-wide sluices have reportedly processed up to 200 yd^3/h. Of course, a sluice will handle as much gravel as the operator wants to push through it. However, to ensure reasonable recovery, capacity is limited by box width and slope, water availability, and feed characteristics.

Feed slurry densities are highly variable and range from 1% to 35% solids by weight, averaging 10%. Water usage can be reduced significantly if the larger of the oversize is eliminated from the feed. Sluices require no power to operate unless a pump is needed to transport water or slurry. One disadvantage of the sluice is the necessity to halt operations in order to recover concentrates.

Spiral Concentrators

Spirals are used infrequently in the western United States but may be applicable for certain types of feed. These gravity separation devices exhibit several desirable features. They accept sized slurry directly, and require no energy to operate other than perhaps pumps for material feed. Pumps can be excluded if gravity feed is used. Selectivity is high due to adjustable splitters within the slurry flow. Spirals can be used to produce a bulk concentrate, scavenge valuable minerals from tailings, or in some instances, recover a finished concentrate. The ability to produce a finished concentrate will be limited to feeds that contain a higher concentration of desired product than typically found in most gold placer feeds.

To save space, two or three spiral starts are constructed around a common vertical pipe. This arrangement takes little floor space, allowing banks of multiple units to be set up for large capacity requirements. In this situation, slurry distributors are required to sectionalize feed for individual spirals.

Maximum feed rates vary according to feed particle density, size, and shape. Rates generally range from 1.0 to 1.4 yd^3/h roughing down to 0.3 to 0.5 yd^3/h cleaning per start. Feed slurry density is typically less than 25% solids by weight, necessitating the use of larger pumps than needed for jigs or tables.

27

Table Concentrators

Concentrating tables (shaking tables) are one of the oldest methods of mechanical gravity concentration. Although capable of handling a variety of feed types and sizes, their optimum use is wet gravity cleaning of fine concentrates ranging from 15 um to 1/8 in. The unit consists of a large, flat, smooth table, slightly tilted, with riffles attached to the surface. A longitudinal reciprocating motion is introduced to the deck by means of a vibrating mechanism or an eccentric head action.

Although limited in capacity, tables have the advantage of being easily adjustable by regulating the quantity of wash water and altering the tilt angle of the deck. The results of these changes are immediately observable on the table. With the addition of splitters, efficient control of high-grade concentrate recovery, middling recovery, and tailings production is possible.

Solids content for table feeds average approximately 25% by weight. Stroke length and speed are adjusted according to feed. Long strokes at slow speeds are used for coarse feeds; fine material responds better to short strokes at higher speeds. A reciprocating speed of 280 to 380 strokes/min will handle most feeds. Table capacities range from 0.05 to 8 yd^3/h and depend on desired product as well as equipment size.

Trommels

This machine is the most common size classification device used in gold placer mills and is well suited for this task if properly designed. Trommels consist of a long rotating cylinder that is typically divided into two sections.

In the first, lengths of angle iron or similar material are fastened to the inside of the rotating drum. These act as lifters to carry feed up the side of the rotating cylinder. As material reaches the top of the rotation, it falls back to the bottom of the cylinder and breaks upon impact. This action, along with water introduced under pressure, serves to break up compacted soils and clays, and liberate valuable minerals.

The second section consists of perforations in the cylinder walls positioned along the length of the drum. Typically, perforation size will graduate from 1/8 in, to 3/16 in, to 1/4 in as the feed progresses down the trommel.

Sized fractions are drawn directly below the section of the trommel in which they are separated. They generally flow to either a vibrating screen to be sized further or to a gravity separation device. Oversize material is discharged out the end of the trommel as waste.

28

Trommels are particularly well adapted to placer feeds because of their ability to handle a diversity of feed sizes and to break up material in the scrubber section. Capacity ranges from 10 to 500 yd^3/h and is dependent on feed characteristics, screen perforation sizes, and machine size. Water requirements are contingent upon the amount of washing desired.

Vibrating Screens

Vibrating screens are often used for secondary size classification in circuits treating alluvial ores and, in some cases, may provide primary sizing. The machines consist of a deck, or decks, containing inclined screening surfaces that are vibrated in either a rectilinear or elliptical motion. Screening medium can be woven wire cloth, parallel bars, or punched sheet metal.

High capacity, ease of installation, and reasonable operating costs have all contributed to the popularity of vibrating screens. The practical minimum size limitation for production screens is about 100 mesh, although 325 mesh separations have been achieved. Capacity is, of course, dependent on many factors. These include type of material, amount of oversize, amount of undersize, moisture content, particle shape, screen opening size, and screen medium. In general, from 0.40 to 0.75 ft^2 of screen surface area will be needed for every cubic yard of feed handled per hour.

Sample Mill Design

It is not possible to provide complete instruction on mill design within the constraints of this manual. Mills must be planned with the intention of treating the size, shape, and grade characteristics of a specific feed. Sample gold mill flow sheets shown in figures 1, 2, and 3 are included to aid the evaluator in cost estimation only. They are provided to demonstrate that, in most instances, material will have to be fed, washed, sized, and separated for proper recovery.

Tables 1, 2, and 3 demonstrate material balance calculations for these mills.

```
                              ┌─────────────────────┐
                              │  10-ton capacity    │
                              │  rear-dump truck    │
                              └─────────────────────┘
                                        │
                              Mine-run gravel
                              (12 yd³/h)
                              ┌─────────────────────┐
                              │   Feed hopper       │
                              └─────────────────────┘
                              ┌─────────────────────┐
                              │   Feed belt         │
                              └─────────────────────┘
Oversize◄──Plus 0.5 in──     ┌─────────────────────┐
           (7.5 yd³/h)       │   Trommel           │◄────(200 gpm)────┐
┌──────────┐                 └─────────────────────┘                  │
│ Conveyor │                                                          │
└──────────┘                  Minus 0.5 in                            │
                              (4.5 yd³/h)                             │
┌──────────┐                 ┌─────────────────────┐                  │
│  Dump    │◄──Tails────     │   Sluice            │────►Water        │
└──────────┘   (4.49 yd³/h)  └─────────────────────┘                  │
                                                        ┌─────────────────┐
                              Concentrates              │ Settling pond   │
                              (0.01 yd³/h)              └─────────────────┘
                              ┌─────────────────────┐   ┌─────────────────┐
                              │   Panning           │   │   Pump          │
                              └─────────────────────┘   └─────────────────┘
                                        │
                              Gold product              Recycled water ────►
```
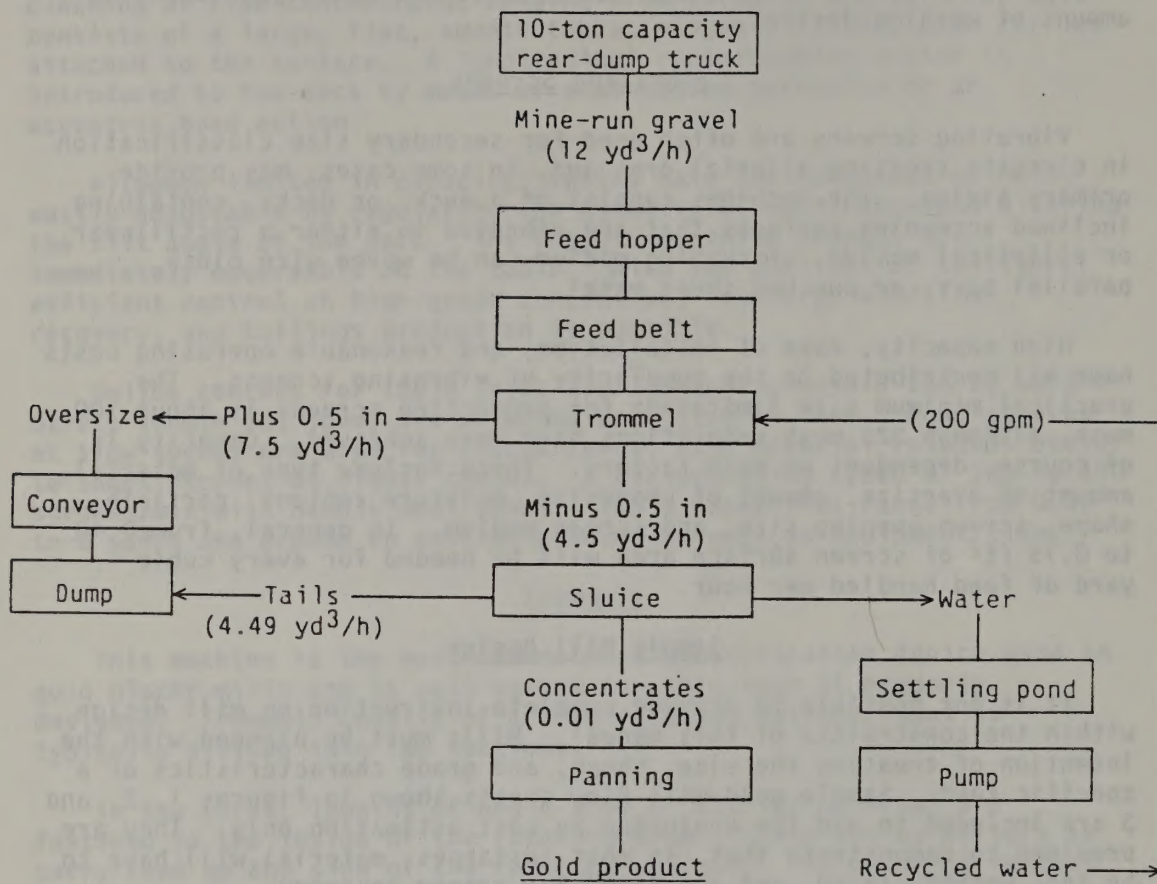
FIGURE 1. - Sample flow sheet, sluice plant.

Dragline

Mine-run gravel
(70 yd³/h)

←—Plus 4 in—— Grizzly ←———— (800 gpm) ————
(5 yd³/h)

minus 4 in

←—Plus 1.5 in—— Vibrating →Minus 1.5 to plus 0.5 in
(20 yd³/h) screen (15 yd³/h)

Minus 0.5 in Sluice ——Waste——
(30 yd³/h) (15 yd³/h)

Plus 0.5 in———
nuggets

Sluice ——Minus 0.5 in——
nuggets

Waste← Rougher Jig tray
(28 yd³/h) jig Plus 0.125 in nuggets

Minus 0.125 in concentrate
(2 yd³/h) Gold product

Jig sump

Jig pump

Dewatering
bin

←— Waste — Cleaner
(1.5 yd³/h) jig

Gold and black sands
(0.5 yd³/h)

←—Black sand— Final jig →Water
(0.49 yd³/h)

Concentrate Settling pond
(0.01 yd³/h)

Panning Pump

Scavenger
sluice

Gold product

Gold product Recycled water——

Dump

FIGURE 2. - Sample flow sheet, jig plant.

31
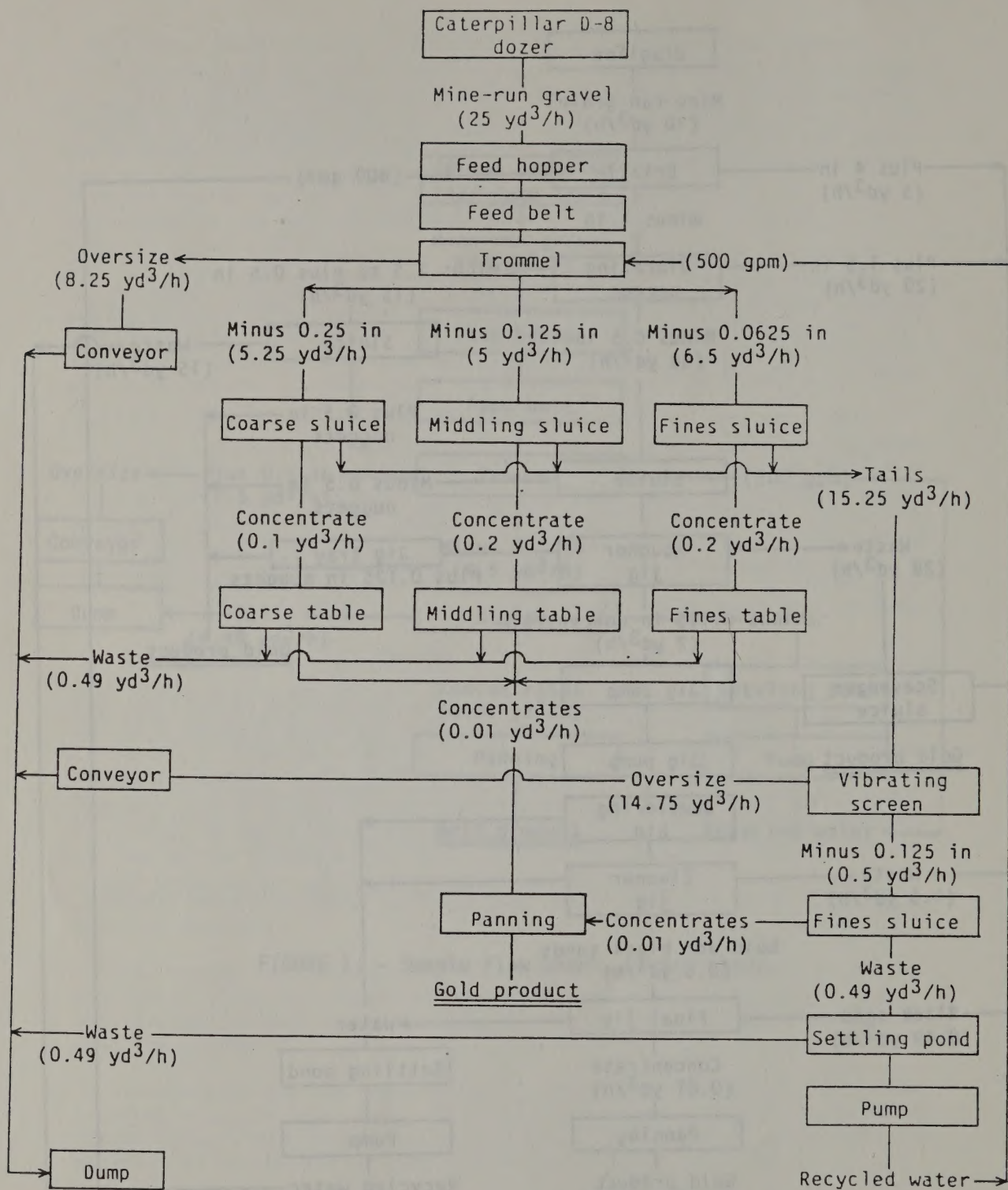
FIGURE 3. - Sample flow sheet, table plant.

TABLE 1. - Sample material balance, sluice plant

Item	Rate yd³/d	wt %	sp gr	Grade tr oz/yd³	Gold tr oz/d	Distribution % Au
Feed	120.0	100.00	2.81	0.040	4.800	100
Concentrates....	0.1	0.08	2.82	42.240	4.224	88
Tails...........	119.9	99.92	2.81	.005	0.576	12
Gold...........			17.50			
Waste..........			2.81			

TABLE 2. - Sample material balance, jig plant

Item	Rate yd³/d	wt %	sp gr	Grade tr oz/yd³	Gold tr oz/d	Distribution % Au
Feed...........	700.0	100.00	2.65	0.030	21.00	100
Concentrates....	0.1	0.01	2.71	199.500	19.95	95
Tails...........	699.9	99.99	2.65	.002	1.05	5
Gold...........			17.50			
Waste..........			2.65			

TABLE 3. - Sample material balance, table plant

Item	Rate yd³/d	wt %	sp gr	Grade tr oz/yd³	Gold tr oz/d	Distribution % Au
Feed...........	250.0	100.00	2.73	0.045	11.250	100
Concentrates....	0.2	0.08	2.75	53.440	10.688	95
Tails...........	249.8	99.92	2.73	.002	0.562	5
Gold...........			17.50			
Waste..........			2.73			

SUPPLEMENTAL SYSTEMS

Commonly neglected in costing and design work, supplemental systems gain importance in placer operations. Due to the relative low cost of placer mining and milling equipment and systems, the expenses associated with supplemental items represent a larger percentage of the total cost than with other types of mining. For costing purposes, any system, structure, or equipment not directly related to production but necessary for continued operation is categorized as supplemental. These include:

1. Buildings.
2. Camp facilities.
3. General services and lost time.
4. Generators.
5. Pumps.
6. Settling ponds.

Each item included in the supplemental section should be examined to determine if it is needed at a particular operation. To aid in this determination and to assist in cost estimation of supplemental items, the following information will prove helpful:

1. Location and elevation of available water in reference to the millsite.
2. Ecological sensitivity of the area.
3. An estimate of the number and capacity of pumps needed.
4. Maximum hourly capacity of mill.
5. Building requirements.
6. An estimate of work force size.

Buildings

Many placer operators consider any building to be a luxury; however, if weather is a factor or if operators desire to safely store equipment, some buildings will be needed. Typically, a small placer mine will have one structure that serves as a shop, a concentrate cleanup area, and a storage room. More elaborate operations, or those in areas of bad weather, will cover the mill and often construct several small storage sheds. These buildings are usually temporary structures of minimal dimensions constructed of wood or metal.

The size of each building must be estimated for costing purposes. For the typical operation, the main structure will be capable of housing the largest piece of mobile equipment at the mine with enough additional room for maintenance work. Shops often have concrete floors, and power and water facilities are typically provided. Storage sheds are usually of minimum quality, have a wood floor if any at all, and often contain power for lighting. Factors for all the above variables are provided in the building cost estimation curve.

Camp Facilities

The provision of facilities for workers is an important part of placer operations. In most situations, workers will stay at the site during the mining season to take advantage of good weather. The needs of these workers must be met, and that typically involves providing living quarters and food. In almost all cases, employee housing at placer mines consists of mobile homes or trailers with a minimum amount of support equipment. Cooking is generally done by the workers in their trailers with an allowance provided for the cost of food.

To calculate the expense of camp facilities, it is necessary to estimate the number of people staying at the mine. Guidelines for this estimate are provided with the cost equations. It must be remembered that the number of people working at any one operation can be quite variable, and if the number of intended or actual employees is available, this figure must be used.

General Services and Lost Time

Compared to other methods of mineral recovery, placer mining is relatively inefficient. Because of limits in workforce size, delays and tasks not directly related to mining have a noticeable effect on productivity. This inefficiency strongly influences costs associated with placer mining, and must be taken into account.

In placer mining, most costs associated with ineffiency can be attributed to three distinct areas:

1. Equipment downtime.
2. Site maintenance.
3. Concentrate refinement.

Specific expenses can be further delineated.

1. Equipment downtime.
   A. Productivity lost by the entire crew due to breakdown of key pieces of equipment.
   B. Productivity lost by individual operators due to breakdown of single pieces of equipment.
   C. Labor charges of outside maintenance personnel.

2. Site maintenance.
   A. Road maintenance.
   B. Stream diversion.
   C. Drainage ditch construction and maintenance.
   D. Site cleanup.
   E. Reclamation grading and recontouring.
   F. Settling pond maintenance.
   G. Mill relocation.

35

3. Concentrate refinement.
   A. Concentrates panning.
   B. Mechanical separation.
   C. Amalgamation.

Estimates indicate that in placer mining up to 37% of the total labor effort is spent on the above tasks. The "Lost Time and General Services" cost curve must be used in all placer mine cost estimates.

Generators

In all but the most simple gravity separation mills, power will be needed to operate equipment. A minor amount of power will also be required for camp functions. Typically, power is provided by one of three sources:

1. Individual diesel engines driving each piece of equipment.
2. Diesel generators.
3. Electrical power brought in through transmission lines.

The third method mentioned above generally requires excessive initial capital expenditures. Transmission lines are considered only when the mill capacity is well over 200 yd^3/h, existing transmission lines are located near the site, or the mine life is expected to be 15 yr or more. Power source selection should be based on lowest overall cost and minimum environmental impact. For most small- to medium-sized gravity separation mills in remote locations, diesel generators are selected to provide power.

Cost estimation curves in this manual are based on diesel generators providing all power to mill equipment. Electric power costs contained in individual processing equipment operating cost curves account for diesel generator operating costs.

Pumps

Water, used to wash gravel and to initiate slurrying of the feed, is typically introduced as gravel enters the trommel or screen. More water is added as needed throughout the circuit to dilute the slurry or assist in washing. To provide adequate washing, this water must be introduced under pressure which, in many cases, necessitates the use of pumps. Pumps will also be needed if mill water is to be recycled through settling ponds. Under certain circumstances, one pump can handle all tasks required in a placer processing plant utilizing recycled water. It is preferable to minimize the use of pumps by taking advantage of gravity.

Water usage is dependent on several factors, including:

1. Washing required to properly slurry feed.
2. Type of separation equipment used.
3. Availability of water.
4. Size and nature of valuable mineral constituents.

For costing purposes, the evaluator must estimate the volume of water pumped per minute and the pumping head. A separate estimate must be made for each pump. Water requirements can either be calculated using parameters given in the processing section of this manual, or roughly estimated using the following equation:

$$\text{Water consumption (gpm)} = 94.089(X)^{0.546}$$

where X = maximum cubic yards of mill feed handled per hour.

This equation provides the total gallons of water per minute consumed by the mill. Although not technically accurate, for our purposes head may be estimated as the elevation difference between the pipe outlet at the mill or upper settling pond, and the pump intake.

Settling Ponds

With the current level of environmental awareness, it is almost assured that mill water will have to be treated prior to discharge. Placer mines typically recycle mill effluent through one or more settling ponds to control environmental impact.

To calculate the cost of settling pond construction using this manual, only the maximum mill feed rate is required. Cost curves provide the construction expense of unlined ponds sized to comply with most regulations. In some instances, the pond will have to be lined with an impervious material. This is often required in ecologically sensitive areas, or in situations where underlying soils do not properly filter mill effluent, thereby increasing the turbidity of nearby streams. A factor is provided in the settling pond cost curve for impervious linings.

ENVIRONMENT

Environmental costs are often decisive in placer mine economic feasibility. Costs associated with water quality control and aesthetics are inescapable and can represent a significant percentage of total mining expenses. Methods to minimize ecological disturbance are now considered an integral function of the mining sequence and are treated as such in cost estimation.

Stream siltation from mill effluent and land disturbance from excavation are the main environmental problems facing placer miners. Water quality is often the biggest problem, and many techniques have been devised to lessen impact. One method involves limiting mill operation to short periods of time, thus allowing effluent to disperse before additional mill discharge is introduced. Often the mill is designed with the intent of using as little water as possible for valuable mineral separation. The most common solution is mill water recirculation facilitated by the construction of settling ponds. These ponds are used to hold mill effluent until particulate matter has settled; water from the ponds is then reused in the mill circuit.

Mining of alluvial deposits necessitates disturbance of large areas of land. Typically all trees, brush, grasses, and ground cover will be cleared. This task alone may present a major stumbling block, since some states restrict open burning. Next, a layer of overburden is removed to expose the deposit. Finally, the valuable mineral-bearing gravel can be excavated.

Current technology suggests that control of land disturbance be incorporated into the mining sequence. Mill tailings and oversize are typically dumped back into worked out areas. Soil cover and overburden are removed just prior to pay gravel excavation, then hauled to mined out areas to be graded and contoured over replaced tails. Often the surface is revegetated. In most instances, the operator will have no choice but to implement ecological control and reclamation procedures. Operators are typically required to post a bond to cover the cost of reclaiming mined lands, and if the surface is left disturbed, these bonds will be forfeited.

Regulations vary from state to state, and may appear difficult and confusing at first; however, by contacting information services at State capitals, operators will be directed to the agencies concerned. These agencies will detail regulations concerning placer operation and will also point out which Federal agencies might be involved (U.S. Forest Service or U.S. Bureau of Land Management). In most instances, contact will have to be made with both State and Federal agencies. Typically, meeting environmental requirements for the State will satisfy Federal regulations.

As stated earlier, environmental control is an integral part of mine and mill design, and costs are treated accordingly. Equations are provided for calculating the cost of mill tails and oversize placement. Expenses associated with grading and contouring are contained in the "Lost Time and General Services" curve. An equation is also provided for the construction of settling ponds, if water is to be recycled.

Bond costs are not included since requirements are highly variable. One other cost may arise that is not covered in section 2. This is the expense of replanting, and usually ranges from $100 to $200/acre.

COST ESTIMATION

After selecting exploration, mining, milling, and supplemental techniques, the next step in cost estimation is the choice of appropriate cost curves. If the evaluator has completed the mine design prior to attempting cost estimation, this task consists of simply going through section 2 of the manual and selecting the proper equations. The list of Capital and Operating categories found at the beginning of section 2 will aid in choosing individual curves.

Costs used in deriving the estimation equations in this handbook were collected from several sources. These include:

1. Placer mine operators.
2. Mine equipment suppliers.
3. Published cost information services.

In all cases, cost figures quoted in the text and points used in cost equation derivations are averages of all data available. A bibliography of cost information publications follows section 2. Many of these sources contain both cost and capacity information and can be used to supplement this manual.

Cost estimation methodology in this handbook is based on the Bureau's Cost Estimation System (CES), first published in 1977 as 'Capital and Operating Cost Estimation System Handbook' by STRAAM Engineers, Inc. Procedures for cost estimation using this handbook closely follow that publication. The cost estimation portion of this handbook is divided into operating and capital costs. Cost equations are similar for both with the only difference appearing in the units of the final answer. Capital costs are given in total dollars amount and operating costs in dollars per year.

Using the appropriate curves, a separate cost is calculated for each capital and operating cost item. Only costs directly associated with the operation under evaluation need be calculated. All other cost items should be ignored. After calculation, item costs should be entered on the respective capital and operating cost summary forms on tables 6 and 7.

Upon summation of individual expenses, a contingency may be added to both capital and operating costs. It is difficult to anticipate every condition that may arise at a particular operation, and the purpose of the contingency is to account for unseen expenditures. This figure is typically based on the degree of certainty of the evaluation in relation to available information, and ranges from 10 to 20%.

Cost per cubic yard of pay gravel processed is determined by dividing the sum of all annual operating costs by the total amount of pay gravel processed per year. Summation of individual capital costs produces the total capital cost.

Use of the individual curves is described in the following paragraphs.

Cost Equations

Capital and operating costs are divided into labor, equipment, and supply categories. One, two, or all three of these categories will be present in each cost equation. The sum of costs from each of these categories provides the total cost for any single cost item. To facilitate cost adjustments respective to specific dates, the labor, equipment, and supply classifications are further broken down into sub-categories.

Typically, each cost item will have a number of site adjustment factors. These are provided to account for characteristics specific to a particular deposit. It is these factors which determine the precision of the final cost, so they must be selected and used carefully. Assistance in determining the correct use of a factor, or in understanding the parameters involved in a cost item, may be found in the preceding pages.

To further improve cost estimates, labor rates are also adjustable. Rates can vary greatly for small placer operations. For this reason, adjustments can be made to the fixed rates used in this manual for specific known rates at individual operations.

Cost Date Adjustments

All cost equations were calculated in January 1985 dollars. Costs calculated for any particular cost item are broken down into specific categories and sub-categories to facilitate adjustment to specific dates. These include:

Labor

    1.   Mine labor.
    2.   Processing labor.
    3.   Repair labor.

Equipment

    1.   Equipment and equipment parts.
    2.   Fuel and lubrication.
    3.   Electricity.
    4.   Tires.

Supplies

    1.   Steel items.
    2.   Explosives.
    3.   Timber.
    4.   Construction materials.
    5.   Industrial materials.

For placer mining, most general maintenance and non-overhaul repairs are accomplished by the equipment operator, so repair labor rates are assumed to be equal to those of the operator. If information available to the evaluator indicates that this is not the case, repair labor portions of the total labor cost are stated to facilitate adjustment.

Equipment operating costs are broken down into respective percentages contributed by parts, fuel and lubrication, electricity, and tires. These percentages, listed immediately following the cost equations, are used to calculate specific costs for each sub-category so that they may be updated. Supply costs are broken down and handled in a similar manner.

Cost date indices for the above sub-categories are provided in table 4. Current indices are available from the Bureau of Mines, Western Field Operations Center, East 360 Third Avenue, Spokane, WA 99202. To adjust a cost to a specific date, divide the index for that date by the index for January 1985, and multiply the resulting quotient by the cost calculated for the respective sub-category. An example is shown following table 4.

TABLE 4. - Mining and milling cost escalation factors

Year	Table 1[2] Min Labor (E&E) C-1	Table 2[3] Const Labor ENR Ski Lab	Table 3 Equipment T6,11-2	Table 4 Bits & Steel T6,10-1	Table 5 Lumber T6,08-1	Table 6 Fuel T6,05-7	Table 7 Explosives T6,0679-02	Table 8 Tires T6,0712-0105	Table 9[4] Const Mat ENR Buil Co	Table 10[5] Indust Mat T6,Ind Com	Table 11[6] Transport T5,4011-A2	Table 12 Ind Power T6,0543	Table 13 Ind Chem T6,06-1
1960	$2.61	725	85.8	97.1	92.1	95.5	94.5	113.1	99	95.3	85.9	100.1	NA
1961	$2.64	755	87.3	97.2	87.4	97.2	97.0	109.9	97	94.8	86.9	100.7	NA
1962	$2.70	800	87.5	95.8	89.0	96.1	97.0	94.7	96	94.8	87.6	101.9	NA
1963	$2.75	816	89.0	95.7	91.2	95.1	100.4	96.9	98	94.7	87.8	101.1	NA
1964	$2.81	853	91.2	97.0	92.9	90.7	100.0	97.6	98	95.2	87.5	100.3	96.7
1965	$2.92	892	93.6	97.9	94.0	93.8	99.6	98.8	97	96.4	89.5	100.3	97.5
1966	$3.05	938	96.5	98.7	100.1	97.4	98.1	101.3	99	98.5	91.8	99.8	98.3
1967	$3.19	996	100.0	100.0	100.0	100.0	100.0	100.0	100	100.0	94.1	100.0	100.0
1968	$3.35	1073	105.7	101.9	117.4	98.1	102.3	102.7	127	102.5	96.5	100.9	101.0
1969	$3.61	1174	110.4	107.0	131.6	99.6	104.7	98.3	108	106.0	100.0	102.2	100.3
1970	$3.85	1318	115.9	115.1	113.7	101.0	106.7	105.4	109	110.0	108.9	106.6	100.9
1971	$4.06	1487	121.4	121.8	135.5	106.8	113.3	110.3	133	114.0	123.5	115.5	102.0
1972	$4.41	1621	125.7	128.4	159.4	108.9	115.2	111.3	151	117.9	128.1	123.9	101.2
1973	$4.73	1725	130.7	136.2	205.2	128.6	120.1	115.7	154	125.9	133.0	132.6	103.4
1974	$5.21	1836	152.3	178.6	207.1	223.4	150.0	141.6	167	153.8	155.0	172.3	151.7
1975	$5.90	1983	185.2	200.9	192.5	257.5	178.0	155.4	186.3	171.5	178.4	209.7	206.8
1976	$6.42	2133	198.9	215.9	233.0	276.6	187.2	172.8	205.5	182.4	197.8	226.7	219.3
1977	$6.88	2266	213.7	230.3	276.5	308.1	193.1	181.5	237.7	195.1	211.1	257.0	223.9
1978	$7.67	2405	232.8	253.5	322.1	321.0	208.7	192.0	247.7	209.4	227.3	279.5	225.6
1979	$8.50	2564	256.2	283.5	354.3	444.8	225.6	219.6	269.28	236.5	264.4	305.3	264.0
Jan80	$8.70	2664	275.4	297.3	336.3	582.4	237.1	236.9	280.86	260.3	288.8	334.8	302.6
Jul80	$9.08	2790	290.9	300.4	327.3	693.3	254.4	250.4	289.05	275.6	318.7	376.0	327.8
Jan81	$9.78	2895	304.9	322.8	331.6	736.0	268.5	256.2	298.25	289.9	342.0	393.9	342.8
Jul81	$10.07	3035	324.0	338.7	330.1	818.4	292.8	269.6	312.11	306.0	363.3	429.9	370.4
Jan82	$10.58	3224	337.0	343.1	310.6	802.9	293.2	271.6	324.74	311.7	385.0	454.0	363.8
Jul82	$10.91	3369	346.1	337.4	319.2	777.1	294.8	272.6	330.56	313.0	389.3	471.5	351.2
Jan83	$11.10	3485	348.6	333.2	324.2	727.1	300.4	285.4	342.01	314.0	392.5	482.6	339.9
Jul83	$11.31	3613	352.7	341.3	372.5	694.9	302.8	256.6	357.28	316.6	396.4	492.2	338.8
Jan84	$11.56	3679	354.3	354.1	353.2	669.7	301.3	258.0	355.52	319.2	409.7	492.0	347.7
Jul84	$11.62	3715	358.2	357.2	343.3	674.6	312.4	256.3	357.90	324.0	411.2	525.5	345.7
Jan85	$11.69	3759	360.4	357.4	343.2	636.2	313.4	262.0	358.32	323.2	100.0	524.9	337.7
Jul85	$11.98	3785	362.3	354.6	354.9	630.7	312.1	246.0	363.63	324.3	100.3	540.3	336.9

NA Not available.

[1]All factors based on "Producer Price Indexes," published by U.S. Bureau of Labor Statistics (B.L.S.), base year of 1967 = 100, unless otherwise noted. The table numbers correspond to the cost index numbers in the STRAAM cost handbook.

[2]Based on "Employment & Earnings," (B.L.S.) - Average Hourly Earnings, Mining.

[3]Based on Engineering News Record (E.N.R.) - Skilled Labor (BC), base year 1913 = 100.

[4]Based on E.N.R. MARKET TRENDS - Building Cost.

[5]Beginning of Table 6, Industrial Commodities (table 2 prior to March 1978).

[6]Based on 1969 = 100 until Jan85, from Jan85 to present based on Dec84 = 100, Jul75 factor = 44.9 for Dec84 = 100. For 1969 = 100, Jul75 = 185.7.

Example:

Calculate the cost in July 1985 dollars of extracting and moving pay gravel 300 ft over level terrain using bulldozers. Assume a 200-yd^3/d operation.

Operating costs (from section 2: Operating costs; Mining; Bulldozers):
   Equipment operating cost................ $0.993(200)^{-0.430} = \$0.102/yd^3$
   Labor operating cost.................. $14.01(200)^{-0.945} = \underline{.094/yd^3}$
      January 1985 total................ $\underline{.196/yd^3}$

Sub-category cost (from section 2: Operating costs; Mining; Bulldozers):
   Equipment parts...................... $0.47 \times \$0.102 = \$0.048/yd^3$
   Fuel and lubrication................. $0.53 \times \$0.102 = \$0.054/yd^3$

   Operator labor....................... $0.86 \times \$0.094 = \$0.081/yd^3$
   Repair labor......................... $0.14 \times \$0.094 = \$0.013/yd^3$

Update indices (from table 4):	Sub-category	July 85/Jan.85	Quotient
Equipment parts..............	Equipment....	362.3/360.4	= 1.005
Fuel and lubrication........	Fuel.........	630.7/636.2	= 0.991
Operator labor..............	Mine labor...	11.98/11.69	= 1.025
Repair labor................	Mine labor...	11.98/11.69	= 1.025

Updated costs:
   Equipment parts...................... $1.005 \times \$0.048 = \$0.048/yd^3$
   Fuel and lubrication................. $0.991 \times \$0.054 = \$0.054/yd^3$

   Operator labor....................... $1.025 \times \$0.081 = \$0.083/yd^3$
   Repair labor......................... $1.025 \times \$0.013 = \underline{\$0.013/yd^3}$
      July 1985 total................... $\underline{\$0.198/yd^3}$

Site Adjustment Factors

As stated earlier, adjustment factors determine the precision for cost estimates and must be used carefully. Several factors are provided for each curve, and their use will significantly alter the calculated cost. The following example illustrates factor use:

43

Example:

Calculate the cost of extracting pay gravel in a difficult digging situation and moving it 800 ft up an 8% gradient using bulldozers. Assume a 200-yd^3/d operation (January 1985 dollars).

From section 2: Operating Costs; Mining; Bulldozers:
Equipment operating cost........ $0.993(200)^{-0.430}$ = \$0.102/yd^3
Labor operating cost........... $14.01(200)^{-0.945}$ + $\underline{\$0.094/yd^3}$
    January 1985 total.......... $\underline{\$0.196/yd^3}$

Factors:
Distance...................... $F_D = 0.00581(800)^{0.904}$ = 2.447
Gradient...................... $F_G = 1.041e^{[0.015(10.0)]}$ = 1.209
Digging difficulty factor....... = 1.670
Used equipment factor:
  Equipment................... $U_e = 1.206(200)^{-0.013}$ = 1.126
  Labor....................... $U_l = 0.967(200)^{0.015}$ = 1.047

Factored cost:
From total cost equation for bulldozers:
[\$0.102(1.126) + \$0.094(1.047)] X 2.447 X 1.209 X 1.670 =

    January 1985 total............................ $\underline{\$1.054/yd^3}$

The 500% increase in operating cost illustrated by the above example demonstrates the dramatic effect of using the proper factors. If a cost category contains a factor not applicable to the deposit in question, then simply leave that factor out of the total cost equation.

The variables inserted in the factor equations are generally self-evident. An exception to this is the digging difficulty factor. Parameters for this factor are based on the following:

1. Easy digging--Unpacked earth, sand, and gravel.
2. Medium digging--Packed earth, sand, and gravel, dry clay, and soil with less than 25% rock content.
3. Medium to hard digging--Hard packed soil, soil with up to 50% rock content, and gravel with cobbles.
4. Hard digging--Soil with up to 75% rock content, gravel with boulders, and cemented gravels.

It can be seen from the above list that many deposits will fall into one of the last two categories. Digging difficulty has a dramatic effect on the cost of extraction, so these factors must be chosen carefully.

Bulldozer and backhoe curves both contain a digging difficulty factor. Other excavation equipment, such as draglines, scrapers, and front-end loaders, are generally suited for special digging conditions and are not used in harder ground. Consequently, no digging difficulty factor is provided for these.

Labor Rates

The cost of labor in placer mining is highly variable and cannot be precisely estimated in every case. For the purposes of this manual, only two separate labor rates are used: $15.69/h for mining functions, and $15.60/h for milling. These rates apply to operation, maintenance, installation, and construction labor. The labor portions of each specific cost category are broken out and in this way can be adjusted to the estimators particular labor rate. To accomplish this, multiply the labor cost for each category by the ratio of desired labor rate to handbook labor rate. The following example illustrates this adjustment:

Example:

Calculate the cost of extracting and moving pay gravel 300 ft over level terrain using bulldozers with an operator labor cost of $18.00/h. Assume a 200-yd^3/d operation (January 1985 dollars).

From section 2: Operating Costs; Mining; Bulldozers:
Equipment operating cost......... $0.993(200)^{-0.430}$ = $0.102/yd^3
Labor operating cost............. $14.01(200)^{-0.945}$ = $0.094/yd^3
January 1985 total........... $0.196/yd^3

Labor Adjustment:
Labor operating cost....... ($18.00/$15.69) X $0.094 = $0.108/yd^3

Adjusted Cost:
Equipment operating cost......................... = $0.102/yd^3
Adjusted labor cost.............................. = $0.108/yd^3
January 1985 total........................... $0.210/yd^3

Labor rates are based on wage scales for the western United States (including Alaska) and include a 24% burden. This burden consists of 9.8% workers compensation insurance, 7.0% social security tax, 3.7% State unemployment insurance, and 3.5% Federal unemployment tax. If other costs such as health and retirement benefits are to be included, they must be added on to an estimated labor rate.

To familiarize the reader with the use of this cost estimating system, an example of a complete cost estimate is included in the appendix.

FINANCIAL ANALYSIS

The purpose of this manual is to provide an estimate of capital and operating costs for small placer mines. A distinction must be made between a cost estimate and an economic feasibility analysis. Capital and operating costs are simply two separate variables in a complete economic analysis. To determine the economic feasibility of an operation, the evaluator must consider each of the following:

1. Recoverable value of commodity.
2. Local, State, and Federal taxes.
3. Capital depreciation.
4. Depletion allowances.
5. Desired return on investment.
6. Costs and methods of project financing.
7. Inflation.
8. Escalation.
9. Environmental intangibles.

Economic Feasibility analysis is a subject in itself, and will not be covered here. The above list is included to emphasize the following: A prospect is not economically feasible simply because the apparent commodity value exceeds the total capital and accrued operating costs calculated from this manual.

The costs associated with the above list are real and must be considered when determining the feasibility of a prospect. Any attempt to provide guidelines for determination of feasibility based solely on estimates of capital and operating costs would be highly misleading. There is no quick and easy way to account for the wide variety of situations encountered in economic analysis. Each one of the above items must be examined individually to provide accurate economic feasibility estimates, and a complete cash flow analysis is the only way to ensure that proper results are obtained. To accomplish this, all yearly income and expenses must be tabulated. Then the rate of return over time must be calculated from the resultant profits or losses. The evaluator must consider all factors influencing income and include all expenses as well as account for the value of money over time and choose an acceptable rate of return.

In brief, the operator will have to receive adequate revenues from commodities recovered to:

1. Cover all operating expenses.
2. Recover initial equipment expenditures.
3. Provide for equipment replacement.
4. Cover all exploration and development costs.
5. Pay taxes.
6. Compensate for inflation and cost escalation.
7. Supply a reasonable profit.

Only after enough revenue has been produced to cover all of the above can an operation be considered economically feasible.

BIBLIOGRAPHY

Adorjan, L. A. Mineral Processing. Paper in Mining Annual Review 1984. Min. J. (London), 1984, pp. 217-219.

Bertoldi, M. J. Preliminary Economics of Mining a Thick Coal Seam by Dragline, Shovel-Truck, and Scraper Mining Systems. BuMines IC 8761, 1977, 27 pp.

Daily, A. Valuation of Large, Gold-Bearing Placers. Eng. and Min. J., v. 163, No. 7, July 1962, 9 pp.

Earll, F. N., K. S. Stout, G. G. Griswald, Jr., R. I. Smith, F. H. Kelly, D. J. Emblen, W. A. Vine, and D. H. Dahlem. Handbook for Small Mining Enterprises. MT Bur. Mines and Geol. Bull. 99, 1976, 218 pp.

Gardner, E. D., and P. T. Allsman. Power-Shovel and Dragline Placer Mining. BuMines IC 7013, 1938, 68 pp.

Jarrett, B. M. Development Document for Final Effluent Limitations Guidelines and New Source Performance Standards for the Ore Mining and Dressing Point Source Category. U.S. EPA Document 440/1-82/061, 1982, 656 pp.

Levell, J. H., V. V. Thornsberry, W. G. Salisbury, and D. A. Smith. 1983 Mineral Resource Studies: Kantishna Hills and Dunkle Mine Areas, Denali National Park and Preserve, Alaska. Volume II. Appendix A (contract S0124031, Salisbury & Dietz, Inc.). BuMines OFR 129(2)-84, 1984, pp. 1-232.

Macdonald, E. H. Alluvial Mining: The Geology, Technology, and Economics of Placers. Chapman and Hall (London), 1983, 508 pp.

McLellan, R. R., R. D. Berkenkotter, R. C. Wilmot, and R. L. Stahl. Drilling and Sampling Tertiary Gold-Bearing Gravels at Badger Hill, Nevada County, Calif. BuMines RI 7935, 1974, 50 pp.

Schumacher, O. L. Placer Gold - Production and Cost History of an Alaska Placer Gold Mine. Western Mine Eng. - Min. Cost Service reprint, Spokane, WA, 1985, 5 pp.

Sharp, A. P., and A. D. Cook. Safety Practices in Churn Drilling at Morenci Branch, Phelps Dodge Corp., Morenci, Ariz. BuMines IC 7548, 1950, 22 pp.

Stout, K. S. The Profitable Small Mine, Prospecting to Operation. McGraw-Hill, 1984, pp. 83-98.

Taggart, A. F. Handbook of Mineral Dressing, Ores and Industrial Minerals. Wiley, sec. 11, 1945, 140 pp.

BIBLIOGRAPHY—Continued

Terrill, I. J., and J. B. Villar. Elements of High-Capacity Gravity
Separation. CIM Bull., v. 68, No. 757, May 1975, pp. 94-101.

Thoenen, J. R., and E. J. Lintner. Churn-Drill Performance. BuMines
RI 4058, 1947, 48 pp.

Thomas, B. I., D. J. Cook, E. Wolff, and W. H. Kerns. Placer Mining
in Alaska: Methods and Costs At Operations Using Hydraulic and
Mechanical Excavation Equipment With Non-Floating Washing Plants.
BuMines IC 7926, 1959, 34 pp.

West, J. M. How To Mine and Prospect for Placer Gold. BuMines IC
8517, 1971, 43 pp.

Wilson, E. D. Gold Placers and Placering in Arizona. AZ Bur. Geol.
and Min. Tech. Bull. 168, 1961, 124 pp.

SECTION 2

COST ESTIMATION
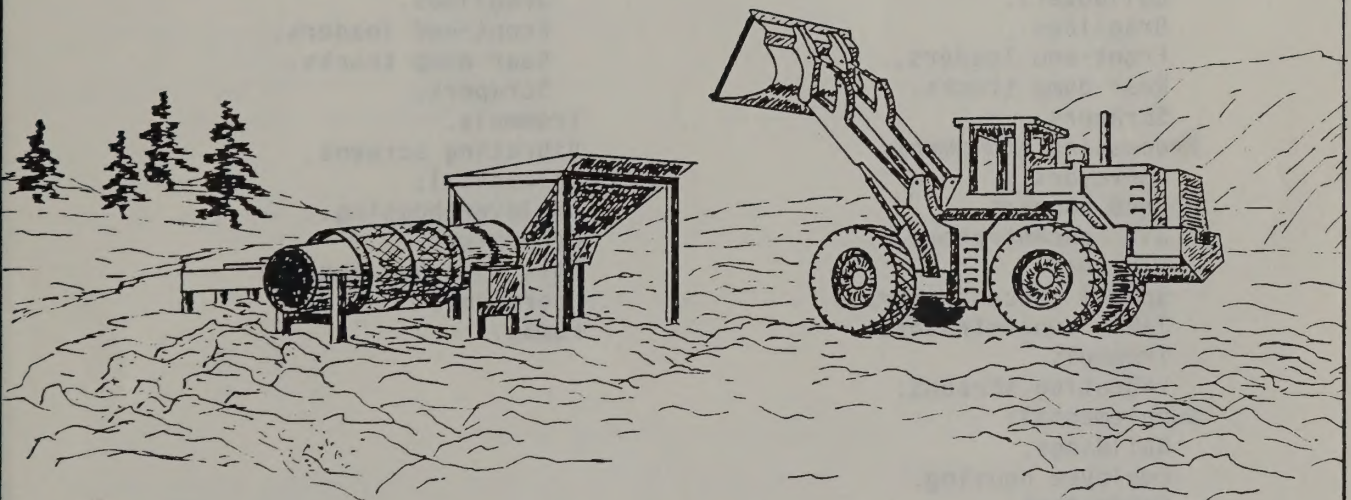
CAPITAL AND OPERATING COST CATEGORIES

Section 2 contains equations for estimating capital and operating costs associated with placer mining. Equations are provided for the following items.

Capital Costs:
  Exploration:
Overburden:
    Exploration.
    Panning.
    Churn drilling.
    Bucket drilling.
    Trenching.
    General reconnaissance.
    Camp costs.
    Seismic surveying
    Rotary drilling.
    Helicopter rental.
  Development:
    Access roads.
    Clearing.
  Overburden removal:
    Bulldozers.
    Draglines.
    Front-end loaders.
    Rear-dump trucks.
    Scrapers.
  Mine equipment:
    Backhoes.
    Bulldozers.
    Draglines.
    Front-end loaders.
    Rear-dump trucks.
    Scrapers.
  Processing equipment:
    Conveyors.
    Feed hoppers.
    Jig concentrators.
    Sluices.
    Spiral concentrators.
    Table concentrators.
    Trommels.
    Vibrating screens.
  Supplemental:
    Buildings.
    Employee housing.
    Generators.
    Pumps.
    Settling ponds.

Operating Costs:

    Bulldozers.
    Draglines.
    Front-end loaders.
    Rear-dump trucks.
    Scrapers.
  Mining:
    Backhoes.
    Bulldozers.
    Draglines.
    Front-end loaders.
    Rear-dump trucks.
    Scrapers.
  Processing:
    Conveyors.
    Feed hoppers.
    Jig concentrators.
    Sluices.
    Spiral concentrators.
    Table concentrators.
    Tailings removal.
      Bulldozers.
      Draglines.
      Front-end loaders.
      Rear-dump trucks.
      Scrapers.
    Trommels.
    Vibrating screens.
  Supplemental:
    Employee housing.
    Generators.
    Lost time and general
      services.
    Pumps.

At the end of this section are summary forms which may be used to aid in total capital and operating cost calculations. A bibliography of cost information sources follows these forms.

The accompanying appendix contains a complete sample cost estimation. This sample will familiarize the reader with cost estimation techniques used in this manual.
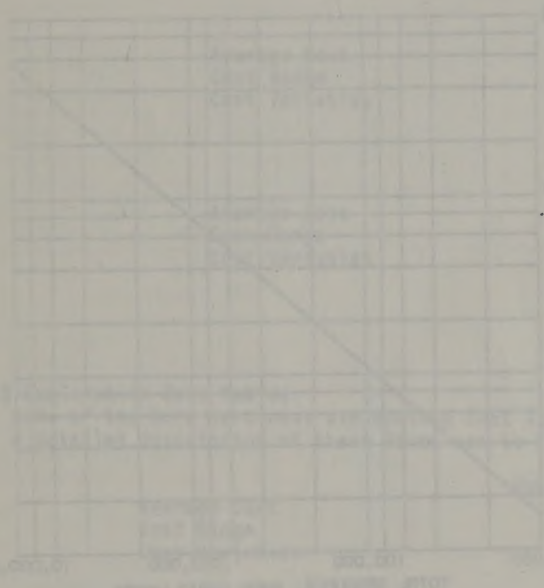
CAPITAL COSTS

Exploration

Exploration

Two methods are presented for calculating exploration costs. Method I allows the evaluator to roughly estimate costs with a minimum of information. Method II requires a detailed exploration plan and provides the user with a much more precise cost.

Method I:

If information concerning exploration of a deposit is not available, the following equation may be used to estimate an exploration capital cost. It must be emphasized, however, that costs calculated from this equation can be very misleading, and it is recommended that a detailed exploration program be designed if possible and that costs be assigned using Method II.

As stated in the text, the amount of exploration required is a highly variable function of many factors. This equation is based on estimated exploration costs for several successful placer operations, but these deposits may have little in common with the one being evaluated.

Base Equation:

The equation is applied to the following variable:
X = Total estimated resource in bank cubic yards

Exploration Capital Cost: $Y_C = 0.669(X)^{0.849}$

An exact breakdown of expenses included in this cost is not available. In general, exploration is a labor-intensive task. Unless the deposit is extremely remote, a large share of the exploration cost will be attributed to labor. If the deposit is remote, costs of access equipment (helicopters, etc.) will become a factor.

Exploration capital costs
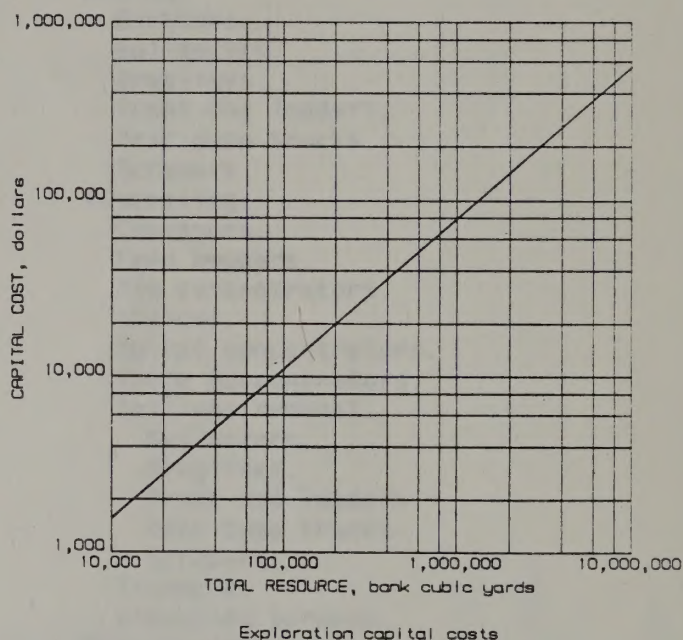
Method II:

Excellent cost data for most exploration functions may be found in the Bureau's Cost Estimating System (CES) manual. Functions covered in that publication include:

Helicopter rental rates.
Sample preparation and analysis costs.
Drill capacities and costs for core, rotary, and hammer drills.
Survey charges.
Labor rates.
Travel costs.
Ground transportation costs.
Field equipment costs.
Geological, geophysical, and geochemical exploration technique costs.

Costs directly related to placer mining from the above list are summarized in the following tables. Several items particular to placer mining are not covered in CES. These items, for which costs follow, include:

Panning.
Churn drilling.
Bucket drilling.
Trenching.

52

Exploration Cost Tables:

As in CES, costs are given in dollars per unit processed (cubic yard, sample, foot drilled, etc.). The product of the unit cost and the total units processed constitutes the total capital cost for any particular method of exploration. Total exploration costs consist of the sum of these individual exploration method expenses. A summary sheet for these calculations follows the cost tables.

Panning

Average Cost	–	$2.10/pan
Cost Range	–	$1.90 to $2.60/pan
Cost Variables	–	Costs are dependent on labor efficiency, and material being panned.

Churn Drilling

Average Cost	–	$45/ft
Cost Range	–	$20 to $70/ft
Cost Variables	–	Costs are dependent on depth of hole, material being drilled, site access, and local competition.

Bucket Drilling

Average Cost	–	$9.20/ft
Cost Range	–	$5 to $20/ft
Cost Variables	–	Costs are dependent on depth of hole, material being drilled, and site access.

Trenching

Average Cost	–	$7.10/yd^3
Cost Range	–	$2.25 to $28.50/yd^3
Cost Variables	–	Costs are dependent on labor efficiency, material being sampled, site access, equipment ownership, sampling method, and total volume of work to be done.

CES Exploration Cost Tables:

Some of the more pertinent exploration cost items presented in the CES manual are summarized below. A detailed description of these items can be found in that publication.

General Reconnaissance

Average Cost	–	$195/worker-day
Cost Range	–	$175 to $210/worker-day
Cost Variables	–	Costs are dependent on deposit access, terrain, and labor efficiency.

Camp Costs

Average Cost	–	$30/worker-day
Cost Range	–	$19 to $41/worker-day
Cost Variables	–	Costs are dependent on deposit remoteness, terrain, access, and climate.

Seismic Surveying (Refraction)

Average Cost	–	$1.25/linear ft
Cost Range	–	$1.00 to $1.50/linear ft
Cost Variables	–	Costs are dependent on labor efficiency, deposit access, and terrain.

Rotary Drilling

Average Cost	–	$6.50/ft
Cost Range	–	$2.00 to $11.50/ft
Cost Variables	–	Costs are dependent on depth of hole, material being drilled, and site access.

Helicopter Rental

Average Cost	–	$395/h
Cost Range	–	$305 to $590/h
Cost Variables	–	Costs are dependent on passenger capacity, payload capacity, cruise speed, and range.

TABLE 5. - Exploration cost summary form

Capital Cost Calculation:

General reconnaissance..	_____ worker-days	X $_____	/worker-day	=	_____
Camp costs.............	_____ worker-days	X $_____	/worker-day	=	_____
Panning................	_____ samples	X $_____	/pan	=	_____
Churn drilling.........	_____ ft drilled	X $_____	/ft	=	_____
Bucket drilling........	_____ ft drilled	X $_____	/ft	=	_____
Trenching..............	_____ yd^3	X $_____	/yd^3	=	_____
Seismic surveying......	_____ linear ft	X $_____	/linear ft	=	_____
Rotary drilling........	_____ ft drilled	X $_____	/ft	=	_____
Helicopter time........	_____ h	X $_____	/h	=	_____
_____ .... _____		X $_____	/_____	=	_____
_____ .... _____		X $_____	/_____	=	_____
_____ .... _____		X $_____	/_____	=	_____
_____ .... _____		X $_____	/_____	=	_____
_____ .... _____		X $_____	/_____	=	_____
_____ .... _____		X $_____	/_____	=	_____
_____ .... _____		X $_____	/_____	=	_____
_ _____ .... _____		X $_____	/_____	=	_____
_____ .... _____		X $_____	/_____	=	_____

_____ Total...

Development

Access Roads

Capital Cost Equation:
This equation provides the cost per mile of road construction to the deposit and between various facilities. Costs include clearing and excavation, but do not account for any blasting or gravel surfacing that may be required. The equation is applied to the following variable:

 X = Average width of roadbed in feet.

The following assumptions were made in estimating road costs:
1. 25% side slope.
2. Moderate ground cover.
3. Moderate digging difficulty.

Base Equation:
 Access road capital cost: $Y_C = 765.65(X)^{0.922}$

The capital cost consists of 68% construction labor, 13% parts, 16% fuel and lubricants, and 3% tire replacement.

Brush Factor:
The original equation is based on the assumption that ground cover consists of a mixture of brush and trees. If vegetation is light (i.e., consisting mainly of brush or grasses), the total cost per mile (covered with brush) must be multiplied by the factor obtained from the following equation:

 $F_B = 0.158(X)^{0.325}$

Forest Factor:
If ground cover is heavy (i.e., consisting mainly of trees), the total cost per mile (covered with trees) must be multiplied by the factor obtained from the following equation:

 $F_F = 2.000(X)^{-0.079}$

Side Slope Factor:
If average side slope of the terrain is other than 25%, the factor obtained from the following equation must be applied to the total cost per mile:

 $F_S = 0.633e^{[0.021(\% \text{ slope})]}$

Development capital costs - Access roads

Surfacing Factor:
If gravel surfacing is required, the cost per mile must be multiplied by the following factor to account for the additional labor, equipment, and supply costs:
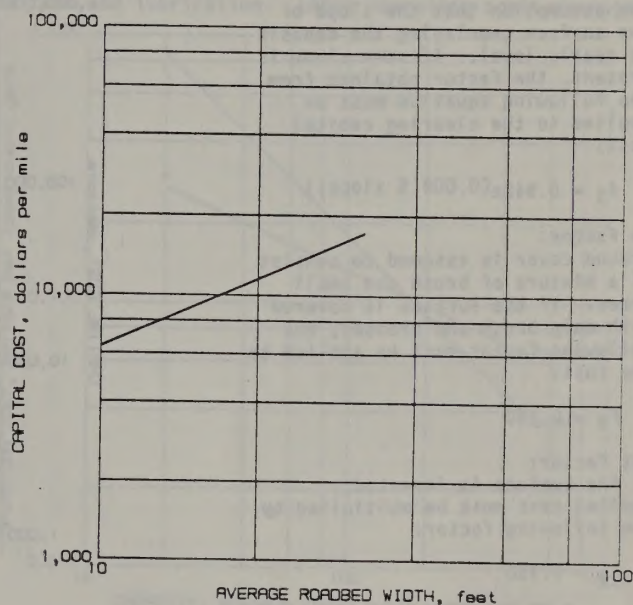
 $F_G = 6.743$

Blasting Factor:
In hard rock situations, blasting may be required. Should this be the case, the cost obtained from the following equation must be __added__ to total access road cost.

 $F_H = [12,059.18(X)^{0.534}] \times [\text{miles of roadbed requiring blasting}]$

Total Cost:
 Access road capital cost $= [(Y_C \times F_B \times F_F \times F_S \times F_G) \times \text{total miles}] + F_H$

This total cost is then entered in the appropriate row on table 6 for final capital cost calculation.

Clearing

Capital Cost Equation:
This equation provides the total capital cost of clearing brush and timber from the surface of a deposit prior to mining. Costs include labor, equipment, and supplies required to completely strip the surface of growth, and to dispose of debris. The equation is applied to the following variable:

X = Total acreage to be cleared.

The following assumptions were made in estimating clearing costs:
1. Level slope.
2. Moderate ground cover.

Base Equation:
Clearing capital cost: $Y_C = 1,043.61(X)^{0.913}$

The capital cost consists of 68% construction labor, 18% fuel and lubricants, 12% parts, and 2% steel supplies.

Slope Factor:
The original equation is based on the assumption that the slope of the surface overlaying the deposit is nearly level. If some slope is present, the factor obtained from the following equation must be applied to the clearing capital cost:

$$F_S = 0.942e^{[0.008(\% \text{ slope})]}$$

Brush Factor:
Ground cover is assumed to consist of a mixture of brush and small trees. If the surface is covered with only brush and grasses, the following factor must be applied to the cost:

$$F_B = 0.250$$

Forest Factor:
If the surface is forested, capital cost must be multiplied by the following factor:

$$F_B = 1.750$$
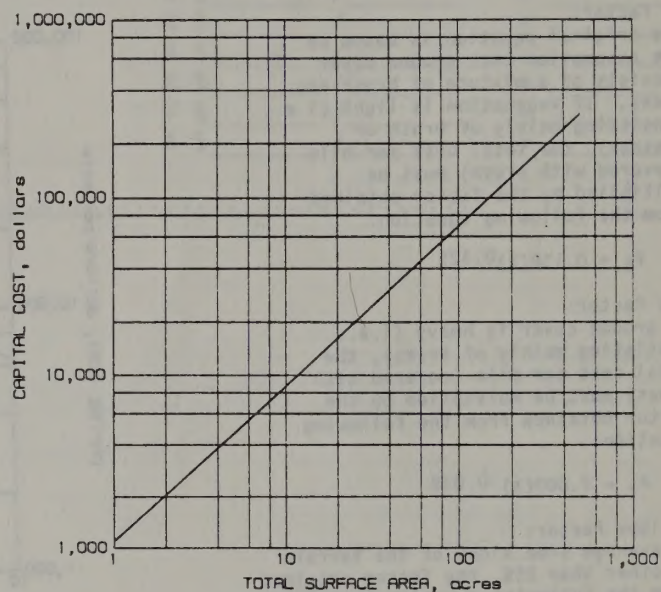
Development capital costs - Clearing

Total Cost:
Clearing capital cost = $(Y_C \times F_S \times F_B)$

This total cost is then entered in the appropriate row on table 6 for final capital cost calculation.

Overburden Removal

Bulldozers

Capital Cost Equations:

These equations provide the cost of excavating and relocating overburden using bulldozers. Costs are reported in dollars per LCY of overburden handled. The equations are applied to the following variable:

X = Maximum LCY of pay gravel, overburden, and tails moved hourly by bulldozer.

The base equations assume the following:
1. No ripping.
2. 50 ft cutting distance.
3. 50 min/h efficiency.
4. 300 ft dozing distance.
5. Average operator ability.
6. Nearly level gradient.

Base Equations:

Equipment operating cost: $Y_E = 0.993(X)^{-0.430}$

Labor operating cost: $Y_L = 14.01(X)^{-0.945}$

Equipment operating costs average 47% parts and 53% fuel and lubrication. Labor operating costs average 86% operator labor and 14% repair labor.

Distance Factor:

If the average dozing distance is other than 300 ft, the factor obtained from the following equation must be applied to total cost per LCY:

$$F_D = 0.00581(distance)^{0.904}$$

Gradient Factor:

If the average gradient is other than level, the factor obtained from the following equation must be applied to the total cost per LCY:

$$F_G = 1.041e^{[0.015(\% \text{ gradient})]}$$

Ripping Factor:

If ripping is required, total operating cost must be multiplied by the following factor:

$$F_R = 1.595$$

This will account for reduced productivity associated with ripping.

Overburden removal capital costs - Bulldozers

Used Equipment Factor:

These factors account for added operating expenses accrued by equipment having over 10,000 h of previous service life. The respective equipment and labor portions of the base operating costs must be multiplied by factors obtained from the following equations:

Equipment factor: $U_e = 1.206(X)^{-0.013}$

Labor factor: $U_l = 0.967(X)^{0.015}$

Digging Difficulty Factor:

Parameters given in the discussion on Site Adjustment Factors in section 1 should be used to determine if a digging difficulty factor is required. If so, one of the following should be applied to total cost per LCY:

F_H = Easy digging = 0.830
Medium digging = 1.000
Medium-Hard digging = 1.250
Hard digging = 1.670

Total Cost:

Cost/LCY overburden = $[Y_E(U_e) + Y_L(U_l)] \times F_D \times F_G \times F_H \times F_R$

To obtain overburden removal capital cost, the above total cost per LCY must be multiplied by total amount of _overburden_ handled by bulldozer prior to production. This product is subsequently entered in the appropriate row on table 6 for final capital cost calculation.
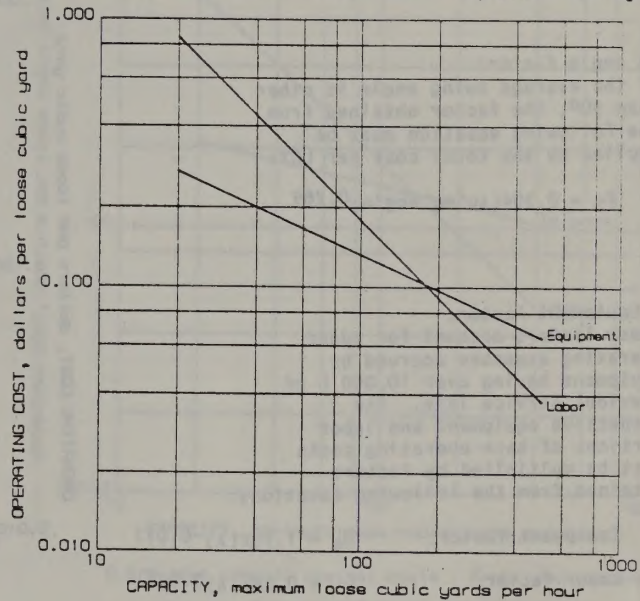
Draglines

Capital Cost Equations:
These equations provide the cost of excavating overburden using draglines. Costs are reported in dollars per LCY of overburden handled. The equations are applied to the following variable:
X = Maximum LCY of pay gravel, overburden, and tails moved hourly by dragline.

The base curves assume the following:
1. 0.90 bucket efficiency.
2. Full hoist.
3. 90° swing angle.
4. Average operator ability.

Base Equations:

Equipment operating cost: $\quad Y_E = 1.984(X)^{-0.390}$

Labor operating cost: $\quad Y_L = 12.19(X)^{-0.888}$

Equipment operating costs consist of 67% parts and 33% fuel and lubrication. Labor operating costs consist of 78% operator labor and 22% repair labor.

Swing Angle Factor:
If the average swing angle is other than 90°, the factor obtained from the following equation must be applied to the total cost per LCY:

$$F_S = 0.304(\text{swing angle})^{0.269}$$

Used Equipment Factor:
These factors account for added operating expenses accrued by equipment having over 10,000 h of previous service life. The respective equipment and labor portions of base operating costs must be multiplied by factors obtained from the following equations:

Equipment factor: $\quad U_e = 1.162(X)^{-0.017}$

Labor factor: $\quad U_1 = 0.989(X)^{0.006}$

Overburden removal capital costs - Draglines

Total Cost:
Cost/LCY overburden = $[Y_E(U_e) + Y_L(U_1)] \times F_S$

To obtain the overburden removal capital cost, the above total cost per LCY must be multiplied by the total amount of _overburden_ handled by dragline prior to production. This product is subsequently entered in the appropriate row on table 6 for final capital cost calculation.

Front-End Loaders

Capital Cost Equations:
These equations provide the cost of relocating overburden using wheel front-end loaders. Costs are reported in dollars per LCY of overburden handled. The equations are applied to the following variable:
X = Maximum LCY of pay gravel, overburden, and tails moved hourly by front-end loader.

The base equations assume the following:
1. 500 ft haul distance.
2. 2% rolling resistance, nearly level gradient.
3. Inconsistent operation.
4. Wheel-type loader.

Base Equations:

Equipment operating cost: $Y_E = 0.407(X)^{-0.225}$

Labor operating cost: $Y_L = 13.07(X)^{-0.936}$

Equipment operating costs average 22% parts, 46% fuel and lubrication, and 32% tires. Labor operating costs average 90% operator labor and 10% repair labor.

Distance Factor:
If the average haul distance is other than 500 ft, the factor obtained from the following equation must be applied to the total cost per LCY:

$F_D = 0.023(\text{distance})^{0.616}$

Gradient Factor:
If total gradient (gradient plus rolling resistance) is other than 2%, the factor obtained from the following equation must be applied to the total cost per LCY:

$F_G = 0.877e^{[0.046(\% \text{ gradient})]}$

Overburden removal capital costs - Front-end loaders

Used Equipment Factor:
These factors account for added operating expenses accrued by equipment having over 10,000 h of previous service life. The respective equipment and labor portions of the base operating costs must be multiplied by factors obtained from the following equations:
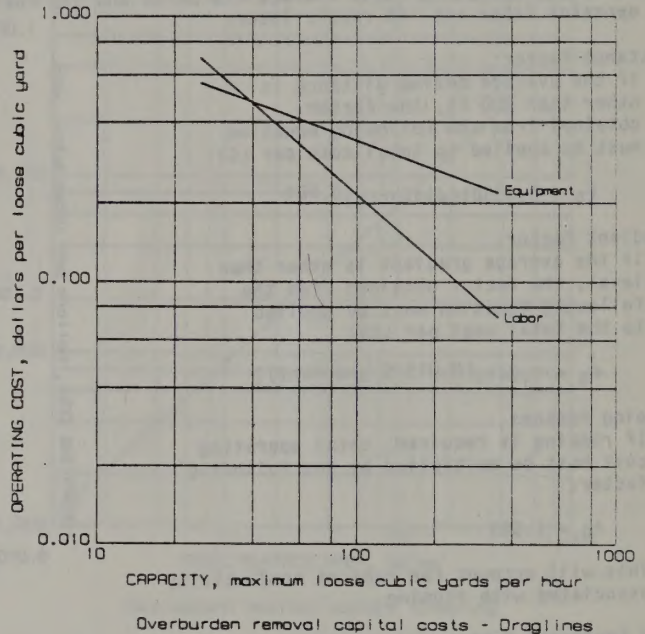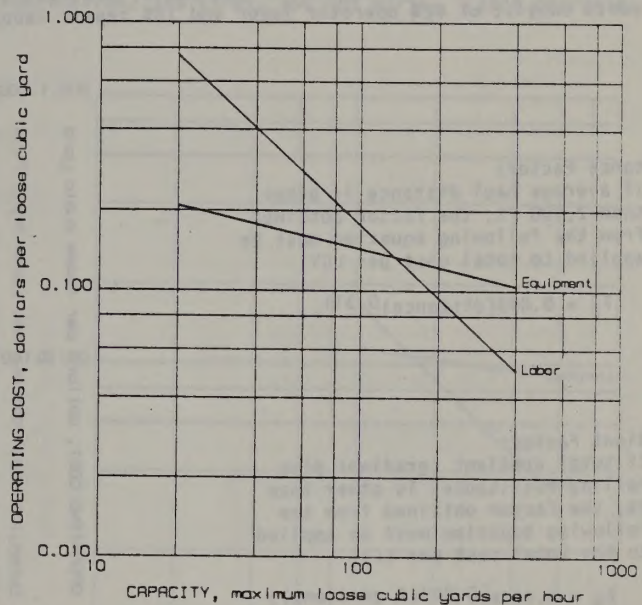
Equipment factor: $U_e = 1.162(X)^{-0.017}$

Labor factor: $U_l = 0.989(X)^{0.006}$

Track-Type Loader Factor:
If track-type loaders are used, the following factors must be applied to the total cost obtained from the base equations:

Equipment factor: $T_e = 1.378$

Labor factor: $T_l = 1.073$

Total Cost:
Cost/LCY overburden = $[Y_E(U_e)(T_e) + Y_L(U_l)(T_l)] \times F_D \times F_G$

To obtain the overburden removal capital cost, the above total cost per LCY must be multiplied by the total amount of overburden handled by front-end loader prior to production. This product is subsequently entered in the appropriate row on table 6 for final capital cost calculation.

59

Capital Cost Equations:
These equations provide the cost of hauling overburden using rear-dump trucks. Costs are reported in dollars per LCY of overburden handled. The equations are applied to the following variable:
X = Maximum LCY of pay gravel, overburden, and tails moved hourly by rear dump truck.

The base equations assume the following:
1. 2,500 ft haul distance.
2. 4 loader cycles to fill.
3. 50 min/h efficiency.
4. Average operator ability.
5. 2% rolling resistance, nearly level gradient.

Base Equations:

Equipment operating cost: $Y_E = 0.602(X)^{-0.296}$

Labor operating cost: $Y_L = 11.34(X)^{-0.891}$

Equipment operating costs consist of 28% parts, 58% fuel and lubrication, and 14% tires. Labor operating costs consist of 82% operator labor and 18% repair labor.

Distance Factor:
If average haul distance is other than 2,500 ft, the factor obtained from the following equation must be applied to total cost per LCY:

$F_D = 0.093(distance)^{0.311}$.

Gradient Factor:
If total gradient (gradient plus rolling resistance) is other than 2%, the factor obtained from the following equation must be applied to total cost per LCY:

$F_G = 0.907e^{[0.049(\% \ gradient)]}$

Operating removal capital costs - Rear-dump trucks

Used Equipment Factor:
These factors account for added operating expenses accrued by equipment having over 10,000 h of previous service life. The respective equipment and labor portions of the base operating costs must be multiplied by factors obtained from the following equations:

Equipment factor: $U_e = 0.984(X)^{0.016}$

Labor factor: $U_l = 0.943(X)^{0.021}$

Total Cost:
Cost/LCY overburden = $[Y_E(U_e) + Y_L(U_l)] \times F_D \times F_G$

To obtain the overburden removal capital cost, the above total cost per LCY must be multiplied by the total amount of overburden handled by truck prior to production. This product is subsequently entered in the appropriate row on table 6 for final capital cost calculation.

Scrapers

Capital Cost Equations:
These equations provide the cost of excavating and hauling overburden using scrapers. Costs are reported in dollars per LCY of overburden handled. The equations are applied to the following variable:
X = Maximum LCY of pay gravel, overburden, and tails moved hourly by scraper.

The base curves assume the following:
1. Standard scrapers.
2. 6% rolling resistance, nearly level gradient.
3. 50 min/h efficiency.
4. 1,000 ft average haul distance.
5. Average operator ability.

Base Equations:
Equipment operating cost: $Y_E = 0.325(X)^{-0.210}$

Labor operating cost: $Y_L = 12.01(X)^{-0.930}$

Equipment operating costs consist of 48% fuel and lubrication, 34% tires, and 18% parts. Labor operating costs consist of 88% operator labor and 12% repair labor.

Distance Factor:
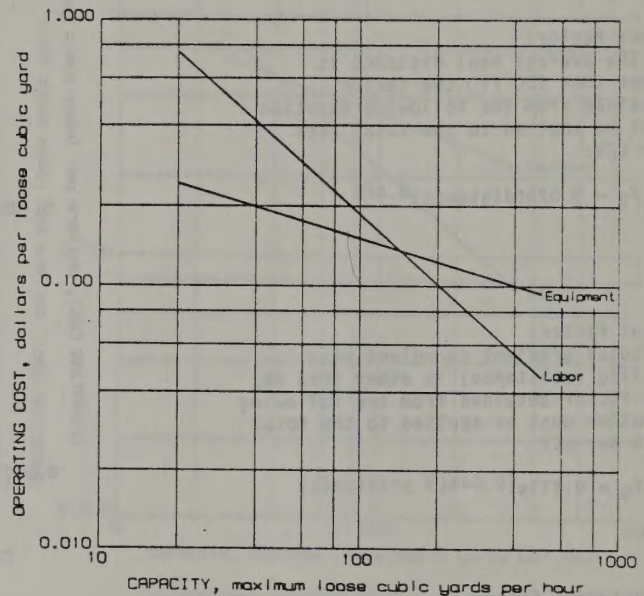If average haul distance is other than 1,000 ft, the factor obtained from the following equation must be applied to total cost per LCY:

$F_D = 0.01947(distance)^{0.577}$

Gradient Factor:
If total gradient (gradient plus rolling resistance) is other than 6%, the factor obtained from the following equation must be applied to total cost per LCY:

$F_G = 0.776e^{[0.047(\% \ gradient)]}$

Overburden removal capital costs - Scrapers

Used Equipment Factor:
These factors account for added operating expenses accrued by equipment having over 10,000 h of previous service life. The respective equipment and labor portions of the base operating costs must be multiplied by factors obtained from the following equations:

Equipment factor: $U_e = 1.096(X)^{-0.006}$

Labor factor: $U_l = 0.845(X)^{0.034}$

Total Cost:
Cost/LCY overburden = $[Y_E(U_e) + Y_L(U_l)] \times F_D \times F_G$

To obtain the overburden removal capital cost, the above total cost per LCY must be multiplied by the total amount of <u>overburden</u> handled by scraper prior to production. This product is subsequently entered in the appropriate row on table 6 for final capital cost calculation.

Backhoes

Capital Cost Equation:
This equation furnishes the cost of purchasing the appropriate number and size of hydraulic-backhoes needed to provide the maximum required production. Costs do not include transportation, sales tax, or discounts. The equation is applied to the following variable:
X = Maximum LCY of pay gravel moved hourly by backhoe.

The following capacities were used to calculate the base equation:

105 hp	–	95.0 to 200.0 LCY/h.
135 hp	–	175.0 to 275.0 LCY/h.
195 hp	–	250.0 to 375.0 LCY/h.
325 hp	–	350.0 to 475.0 LCY/h.

The above capacities are based on the following assumptions:
(1) Medium digging difficulty.
(2) Average operator ability.
(3) $60°$ to $90°$ swing angle.
(4) 0% to 50% maximum digging depth.
(5) No obstructions.

Base Equation:
Equipment capital cost: $Y_C = 84,132.01e^{[0.00350(X)]}$

Equipment capital costs consist entirely of the equipment purchase price.

Digging Depth Factor:
If average digging depth is other than 50% of maximum depth obtainable for a particular make of backhoe, the factor obtained from the following equation must be applied to total capital cost:

$F_D = 0.04484(D)^{0.790}$

where D = percent of maximum digging depth.

Used Equipment Factor:
This factor accounts for the reduced capital expenditure of purchasing equipment having over 10,000 h of previous service life:

$F_U = 0.386$

Digging Difficulty Factor:
Parameters given in the discussion on Site Adjustment Factors in section 1 should be used to determine if a digging difficulty factor is required. If so, one of the following should be applied to total capital cost:

F_H = Easy digging	=	1.000
Medium digging	=	1.330
Medium-Hard digging	=	1.556
Hard digging	=	1.822

Total Cost:
Backhoe capital cost = $Y_C \times F_D \times F_U \times F_H$

This product is subsequently entered in the appropriate row on table 6 for final capital cost calculation.

Mine equipment capital costs - Backhoes

62
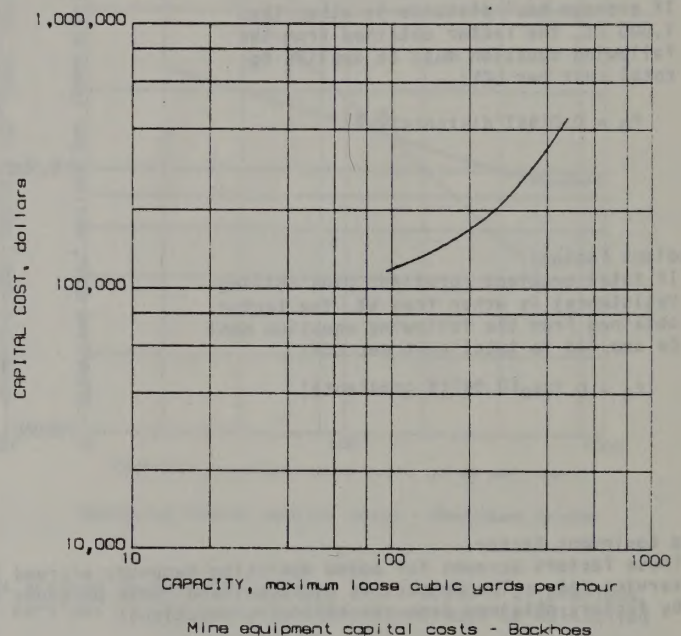
Bulldozers

Capital Cost Equation:

This equation furnishes the cost of purchasing the appropriate size and number of crawler-dozers needed to provide the maximum required production. Costs do not include transportation, sales tax, or discounts. The equation is applied to the following variable:

X = Maximum LCY of pay gravel, overburden, and waste moved hourly by bulldozer.

The following capacities were used to calculate the base equation:

65 hp	–	19.00 LCY/h.
80 hp	–	31.50 LCY/h.
105 hp	–	56.50 LCY/h.
140 hp	–	82.00 LCY/h.
200 hp	–	126.00 LCY/h.
335 hp	–	263.50 LCY/h.
460 hp	–	334.00 LCY/h.
700 hp	–	497.50 LCY/h.

The above capacities are based on the following assumptions:
(1) Straight "S" blades.
(2) No ripping.
(3) Average operator ability.
(4) 50 ft cutting distance.
(5) 300 ft dozing distance.
(6) 50 operating min/h.
(7) Even, nearly level gradient.

Base Equation:

Equipment Capital Cost: $\qquad Y_C = 3,555.96(X)^{0.806}$

Equipment capital costs consist entirely of equipment purchase price.

Distance Factor:

If average dozing distance is other than 300 ft, the factor obtained from the following equation must be applied to capital cost:

$$F_D = 0.01549(Distance)^{0.732}$$

This will correct for the addition or reduction of equipment required to maintain maximum capacity.

Gradient Factor:

If the average gradient is other than level, the factor obtained from the following equation must be applied to total capital cost. This will correct for the addition or reduction of equipment required to maintain maximum capacity. (Favorable haul gradients should be entered as negative, uphill haul gradients as positive.)

$$F_G = 1.041e^{[0.015(\% \ gradient)]}$$

Digging Difficulty Factor:

Variations from the base digging difficulty will necessitate changes in equipment size to maintain production capacity. Parameters given in the discussion on Site Adjustment Factors in section 1 should be used to determine if a digging difficulty factor is required. If so, one of the following should be applied to total capital cost:

F_H = Easy digging	=	0.863
Medium digging	=	1.000
Medium-Hard digging	=	1.197
Hard digging	=	1.509

Used Equipment Factor:

This factor accounts for reduced capital expenditure of purchasing equipment having over 10,000 h of previous service life:

$$F_U = 0.411$$

Total Cost:

Bulldozer capital cost = $Y_C \times F_H \times F_D \times F_G \times F_U$

This product is subsequently entered in the appropriate row on table 6 for final capital cost calculation.

Mine equiment capital costs - Bulldozers
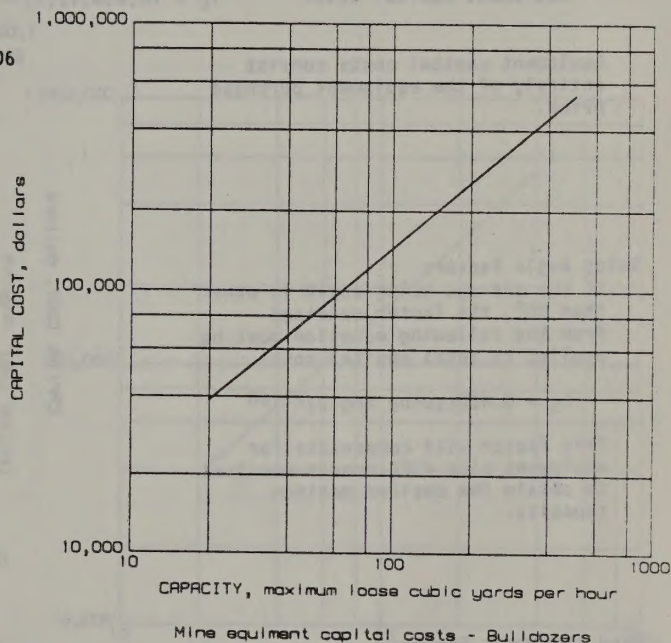
Capital Cost Equation:
This equation furnishes the cost of purchasing the appropriate size dragline needed to provide the maximum required production. Costs do not include transportation, sales tax, or discounts. The equation is applied to the following variable:

X = Maximum LCY of pay gravel, overburden, and waste moved hourly by dragline.

The following capacities were used to calculate the base equation:

84.0 hp	–	28.00 LCY/h.
110.0 hp	–	47.00 LCY/h.
148.0 hp	–	66.00 LCY/h.
170.0 hp	–	75.00 LCY/h.
190.0 hp	–	94.00 LCY/h.
263.0 hp	–	132.00 LCY/h.
289.0 hp	–	188.00 LCY/h.
540.0 hp	–	264.00 LCY/h.

The above capacities are based on the following assumptions:
(1) 0.90 bucket efficiency.
(2) Full hoist.
(3) 90° swing angle.
(4) Average operator ability.

Base Equation:
Equipment capital cost: $Y_C = 16,606.12(X)^{0.678}$

Equipment capital costs consist entirely of the equipment purchase price.

Swing Angle Factor:
If the average swing angle is other than 90°, the factor obtained from the following equation must be applied to total capital cost:

$F_S = 0.450(\text{swing angle})^{0.180}$

This factor will compensate for equipment size differences required to obtain the desired maximum capacity.

Mine equipment capital costs - Draglines
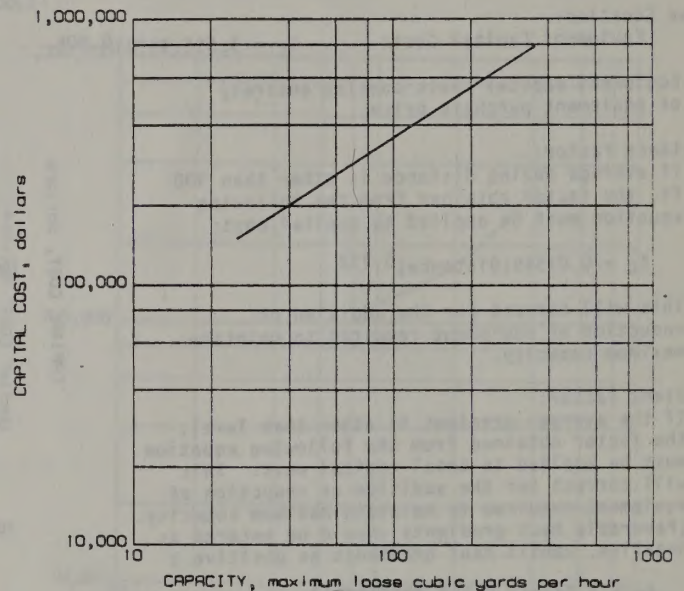
Used Equipment Factor:
This factor accounts for the reduced capital expenditure of purchasing equipment having over 10,000 h of previous service life:

$F_U = 0.422$

Total Cost:
Dragline capital cost = $Y_C \times F_S \times F_U$

This product is subsequently entered in the appropriate row on table 6 for final capital cost calculation.

64

Front-End Loaders

Capital Cost Equation:
This equation provides the cost of purchasing the appropriate size and number of front-end loaders needed to supply the maximum required production. Costs do not include transportation, sales tax, or discounts. The equation is applied to the following variable:
X = Maximum LCY of pay gravel, overburden, and waste moved hourly by front-end loader.

The base equation was calculated using the following capacities:

1.00-yd^3 bucket	(65 hp)	–	24.00 LCY/h.
1.50-yd^3 bucket	(80 hp)	–	34.50 LCY/h.
1.75-yd^3 bucket	(105 hp)	–	38.50 LCY/h.
2.25-yd^3 bucket	(125 hp)	–	56.25 LCY/h.
2.75-yd^3 bucket	(155 hp)	–	66.00 LCY/h.
3.50-yd^3 bucket	(200 hp)	–	129.50 LCY/h.
4.50-yd^3 bucket	(270 hp)	–	171.00 LCY/h.
6.50-yd^3 bucket	(375 hp)	–	234.00 LCY/h.
12.00-yd^3 bucket	(690 hp)	–	348.00 LCY/h.

The above capacities are based on the following assumptions:
1. 500 ft haul distance.
2. 2% rolling resistance, nearly level gradient.
3. Inconsistent operation.
4. Wheel-type loader.
5. 50 operating min/h.
6. General purpose buckets – heaped.

Base Equation:
Equipment capital cost: $Y_C = 2,711.10(X)^{0.896}$

Equipment capital costs consist entirely of the equipment purchase price.

Distance Factor:
If the average haul distance is other than 500 ft, the factor obtained from the following equation must be applied to the capital cost:

$F_D = 0.033(distance)^{0.552}$

This will correct for the addition or reduction of equipment required to maintain maximum capacity. (If tracked loaders are to be used, the maximum haul distance should not exceed 600 ft.)

Gradient Factor:
If total gradient (gradient plus rolling resistance) is other than 2%, the factor obtained from the following equation must be applied to the total capital cost:

$F_G = 0.888e^{0.041(\% \text{ gradient})}$

This will correct for the addition or reduction of equipment required to maintain maximum capacity.

Mine equipment capital costs - Front-end loaders

Used Equipment Factor:
This factor accounts for reduced capital expenditure of purchasing equipment having over 10,000 h of previous service life:

$F_U = 0.386$

Track-Type Loader Factor:
If track-type loaders are used, the factor obtained from the following equation must be applied to total capital cost:

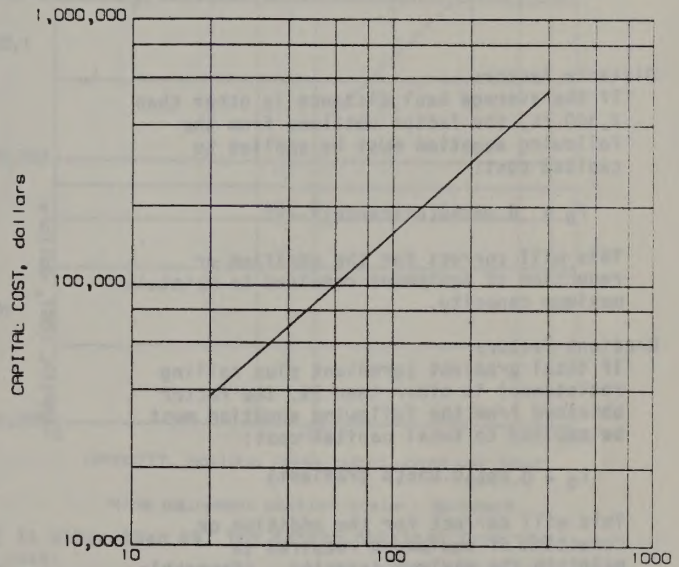$F_T = 0.414(X)^{0.272}$

This factor will account for the decrease in production efficiency and the difference in equipment cost.

Total Cost:
Front-end loader capital cost = $Y_C \times F_D \times F_G \times F_U \times F_T$

This product is subsequently entered in the appropriate row on table 6 for final capital cost calculation.

65

Capital Cost Equation:
This equation furnishes the cost of purchasing the appropriate size and number of diesel rear-dump trucks needed to provide the maximum required production. Costs do not include transportation, sales tax, or discounts. The equation is applied to the following variable:
X = Maximum LCY of pay gravel, overburden, and waste moved hourly by rear-dump truck.

The following capacities were used to calculate the base equation:

3.0-yd^3 truck	–	32.30 LCY/h.
5.0-yd^3 truck	–	53.40 LCY/h.
6.0-yd^3 truck	–	63.60 LCY/h.
8.0-yd^3 truck	–	83.50 LCY/h.
10.0-yd^3 truck	–	104.20 LCY/h.
12.0-yd^3 truck	–	124.50 LCY/h.
16.0-yd^3 truck	–	163.90 LCY/h.
22.8-yd^3 truck	–	223.50 LCY/h.
34.0-yd^3 truck	–	326.30 LCY/h.
47.5-yd^3 truck	–	444.80 LCY/h.

The above capacities are based on the following assumptions:
1. Diesel rear-dump trucks.
2. 4 loader cycles to fill.
3. 2,500 ft haul distance.
4. 2% rolling resistance, nearly level gradient.

Base Equation:
Equipment capital cost: $Y_C = 472.09(X)^{1.139}$

Equipment capital costs consist entirely of the equipment purchase price.

Distance Factor:
If the average haul distance is other than 2,500 ft, the factor obtained from the following equation must be applied to capital cost:

$$F_D = 0.06240(\text{Distance})^{0.364}$$

This will correct for the addition or reduction of equipment required to maintain maximum capacity.

Gradient Factor:
If total gradient (gradient plus rolling resistance) is other than 2%, the factor obtained from the following equation must be applied to total capital cost:

$$F_G = 0.896e^{0.056(\% \text{ gradient})}$$

This will correct for the addition or reduction of equipment required to maintain the maximum capacity. (Favorable haul gradient should be entered as negative, uphill haul grades as positive.)

Mine equipment capital costs - Rear-dump trucks

Used Equipment Factor:
This factor accounts for reduced capital expenditure of purchasing equipment having over 10,000 h of previous service life:

$$F_U = 0.243$$

Total Cost:
Truck capital cost = $Y_C \times F_D \times F_G \times F_U$

This product is subsequently entered in the appropriate row on table 6 for final capital cost calculation.
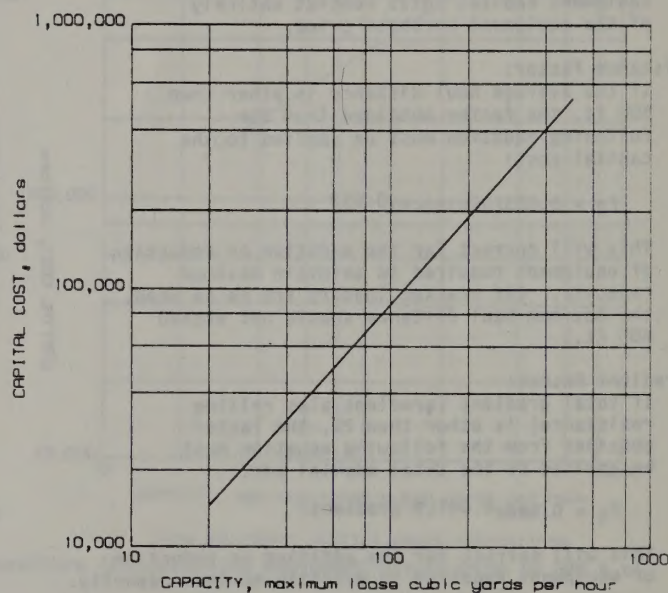
Scrapers

Capital Cost Equation:
This equation furnishes the cost of purchasing the appropriate size and number of scrapers needed to provide maximum required production. Costs do not include transportation, sales tax, or discounts. The equation is applied to the following variable:

X = Maximum LCY of pay gravel, overburden, and waste moved hourly by scraper.

The following capacities were used to calculate the base equation:

330 hp	–	201.00 LCY/h.
450 hp	–	323.00 LCY/h.
550 hp	–	420.00 LCY/h.

The above capacities are based on the following assumptions:
1. Standard scrapers.
2. 6% rolling resistance, nearly level gradient.
3. 1,000 ft average haul distance.
4. Average operator ability.
5. 300 ft dozing distance.
6. 50 operating min/h.

Base Equation:
Equipment capital cost: $Y_C = 1,744.42(X)^{0.934}$

Equipment capital costs consist entirely of the equipment purchase price.

Distance Factor:
If the haul distance is other than 1,000 ft, the factor obtained from the following equation must be applied to the total capital cost:

$$F_D = 0.025(\text{Distance})^{0.539}$$

This will correct for the addition or reduction of equipment required to maintain maximum production capacity.
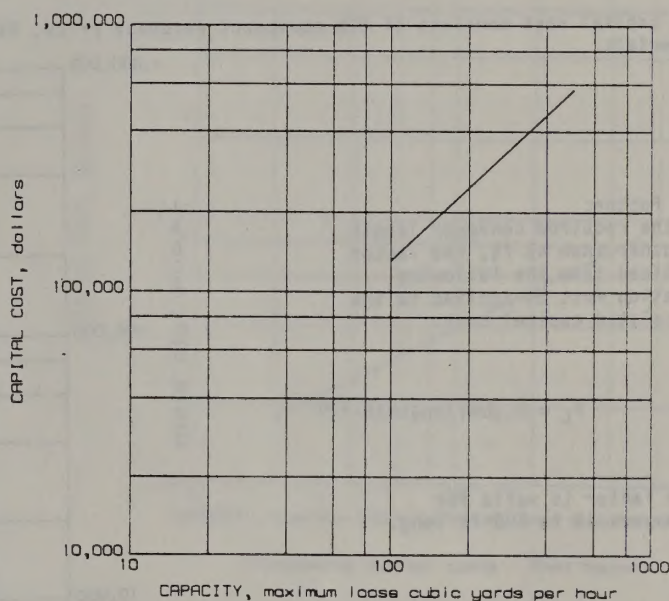
Mine equipment capital costs - Scrapers

Gradient Factor:
If total gradient (gradient plus rolling resistance) is other than 6%, the factor obtained from the following equation must be applied to total capital cost:

$$F_G = 0.776e^{0.047(\% \text{ gradient})}$$

This will correct for the addition or reduction of equipment required to maintain the maximum production capacity. (Favorable haul gradients are entered as negative, uphill haul gradients as positive.)

Used Equipment Factor:
This factor accounts for reduced capital expenditure of purchasing equipment having over 10,000 h of previous service life:

$$F_U = 0.312$$

Total Cost:
Scraper capital cost = $Y_C \times F_D \times F_G \times F_U$

This product is subsequently entered in the appropriate row on table 6 for final capital cost calculation.

Conveyors

Capital Cost Equation:
This equation furnishes the cost of purchasing and installing the appropriate size conveyors needed to meet maximum required production. A separate cost must be calculated for each conveyor in the circuit. The cost includes associated drive motors and electrical hook-up. Equipment transportation, sales tax, and discounts are not accounted for. The equation is applied to the following variable:
X = Maximum cubic yards of material handled hourly by conveyor.

The following capacities were used to calculate the base equation:

18-in conveyor	−	96.0 yd^3/h.
24-in conveyor	−	192.0 yd^3/h.
30-in conveyor	−	320.0 yd^3/h.
36-in conveyor	−	480.0 yd^3/h.

The above capacities are based on the following assumptions:
1. 3,120 lb/yd^3 feed material.
2. 40 ft portable conveyors.
3. Nearly level set-up.

Base Equation:
Equipment capital cost: $Y_C = 4,728.36(X)^{0.287}$

The capital cost consists of 89% equipment purchase price, 8% installation labor, and 3% construction materials.
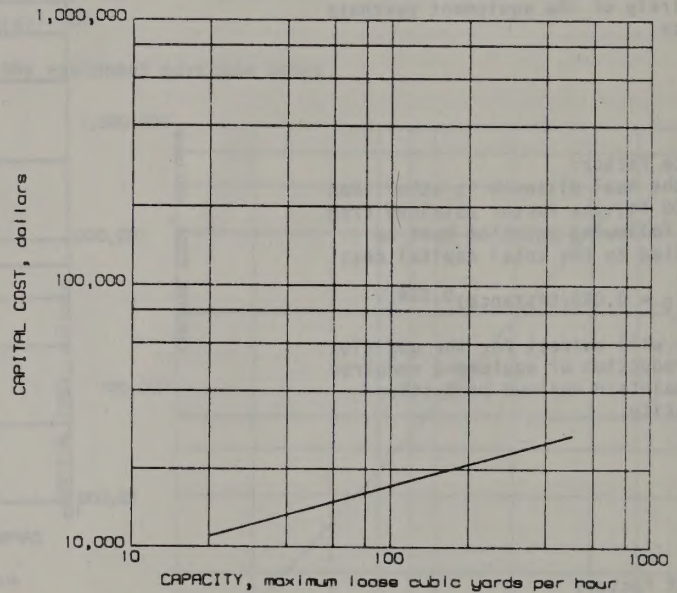
Length Factor:
If the required conveyor length is other than 40 ft, the factor obtained from the following equation must be applied to the calculated capital cost:

$F_L = 0.304(\text{length})^{0.330}$

This factor is valid for conveyors 10 to 100 ft long.

Processing equipment capital costs -Conveyors

Used Equipment Factor:
This factor accounts for reduced capital expenditure of purchasing equipment having over 10,000 h of previous service life:

$F_U = 0.505$

Total Cost:
Conveyor capital cost = $Y_C \times F_L \times F_U$

This product is subsequently entered in the appropriate row on table 6 for final capital cost calculation.

68

Feed Hoppers

Capital Cost Equation:

This equation furnishes the cost of purchasing and installing the appropriate size vibrating feeder needed to meet maximum required production. The cost includes associated drive motors, springs, and electrical hook-up, plus the expense of a hopper. Equipment transportation, sales tax, and discounts are not accounted for. The equation is applied to the following variable:

X = Maximum cubic yards of material handled hourly by feed hopper.

The following capacities were used to calculate the base equation:

12 in wide unit	–	16.0 yd^3/h.
24 in wide unit	–	211.0 yd^3/h.
36 in wide unit	–	522.0 yd^3/h.

The above capacities are based on the following assumptions:
1. Un-sized feed.
2. 2,300 lb/LCY feed density.

Base Equation:

Equipment capital cost: $Y_C = 458.48(X)^{0.470}$

The capital cost consists of 82% equipment purchase price, 14% construction and installation labor, and 4% steel.

Hopper Factor:

In many instances a vibrating feeder may not be required. If a hopper is the only equipment needed, multiply calculated cost by the factor obtained from the following equation:

$$F_H = 0.078e^{[0.00172(X)]}$$

The product will account for material and labor required to construct and install a hopper.
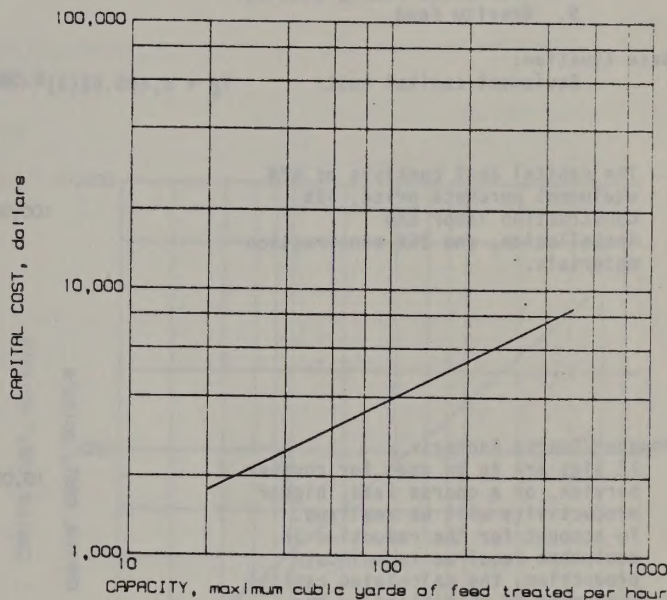
Processing capital costs - Feed hoppers

Used Equipment Factor:

The factor calculated from the following equation accounts for reduced capital expenditure of purchasing equipment having over 10,000 h of previous service life:

$$F_U = 0.476e^{[0.00036(X)]}$$

Total Cost:

Feeder capital cost $= Y_C \times F_H \times F_U$

This product is subsequently entered in the appropriate row on table 6 for final capital cost calculation.

Jig Concentrators

Capital Cost Equation

This equation furnishes the cost of purchasing and installing the appropriate size and number of jigs needed to meet maximum required production. The cost includes associated drive motors, piping, and electrical hook-up. Equipment transportation, sales tax, and discounts are not accounted for. The equation is applied to the following variable:

    X = Maximum cubic yards of feed handled hourly by jig concentrators.

The following capacities were used to calculate the base equation:

12 in x 12 in Simplex	–	0.617 yd^3/h.
26 in x 26 in Simplex	–	2.896 yd^3/h.
36 in x 36 in Duplex	–	11.106 yd^3/h.
36 in x 36 in Triplex	–	16.659 yd^3/h.
42 in x 42 in Triplex	–	22.675 yd^3/h.

The above capacities are based on the following assumptions:
1. Cleaner service.
2. 0.617 yd^3/ft^2 hourly capacity.
3. 3,400 lb/yd^3 feed solids.
4. 40% solids slurry density.
5. Gravity feed.

Base Equation:

Equipment capital cost: $Y_C = 6,403.82(X)^{0.595}$

The capital cost consists of 62% equipment purchase price, 12% construction labor and installation, and 26% construction materials.

Rougher/Coarse Factor:

If jigs are to be used for rougher service, or a coarse feed, higher productivity will be realized. To account for the reduction in equipment required to maintain production, the calculated capital cost must be multiplied by the following factor:

$F_R = 0.531$
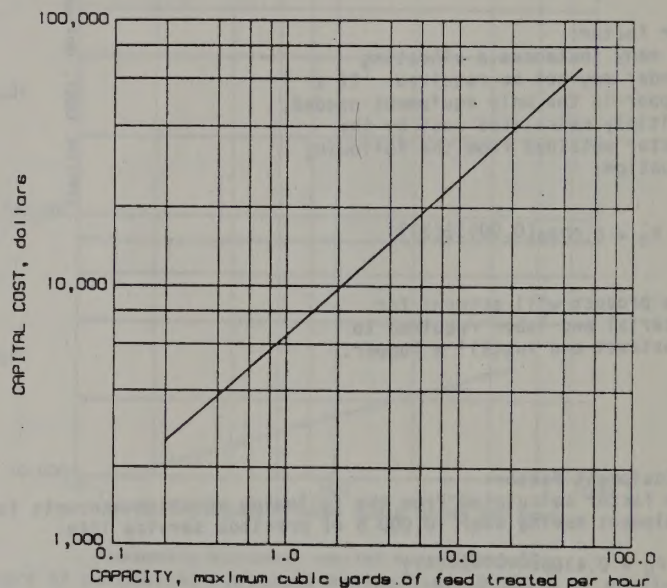
Processing equipment capital costs - Jig concentrators

Used Equipment Factor:

This factor accounts for reduced capital expenditure of purchasing equipment having over 10,000 h of previous service life:

$F_U = 0.697$

Total Cost:

Jig concentrator capital cost = $Y_C \times F_R \times F_U$

This product is subsequently entered in the appropriate row on table 6 for final capital cost calculation.

Sluices

Capital Cost Equation:
This equation furnishes the cost of constructing and installing the appropriate size and number of sluices needed to meet maximum required production. Costs do not include material transportation or sales tax. The equation is applied to the following variable:
X = Maximum cubic yards of feed handled hourly by sluice.

The following capacities were used to calculate the base equation:

18 in-wide Box	-	20.75 yd^3/h.
24 in-wide Box	-	31.25 yd^3/h.
30 in-wide Box	-	50.00 yd^3/h.
36 in-wide Box	-	75.00 yd^3/h.
42 in-wide Box	-	125.00 yd^3/h.
48 in-wide Box	-	218.75 yd^3/h.

The above capacities are based on the following assumptions:
1. Steel plate construction.
2. Angle iron riffles.
3. 3,400 lb/yd^3 feed solids.
4. 4:1 length to width ratio.
5. Gravity feed.

Base Equation:
Equipment capital cost: $Y_C = 113.57(X)^{0.567}$

The capital cost consists of 61% construction and installation labor, and 39% construction materials.

Wood Construction Factor:
If sluices are to be made of wood rather than steel, the following factor will account for reduced material and construction costs:

$F_W = 0.499(X)^{-0.023}$

Length Factor:
This factor will account for changes in the desired length of the sluice. The factor obtained from the following equation must be applied to capital cost:

$F_L = 1.001(L)^{0.753}$

where L = desired length divided by length assumed for the base calculation (width x 4.0)

Processing equipment capital costs - Sluices

Used Equipment Factor:
This factor accounts for reduced capital expenditure of purchasing equipment having over 10,000 h of previous service life:

$F_U = 0.574$

Total Cost:
Sluice capital cost = Y_C x F_W x F_L x F_U

This product is subsequently entered in the appropriate row on table 6 for final capital cost calculation.

71
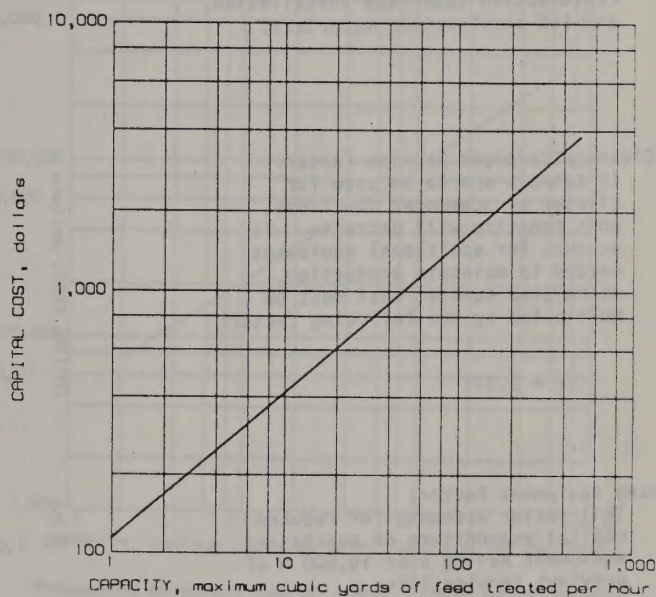
Spiral Concentrators

Capital Cost Equation:
This equation furnishes the cost of purchasing and installing the appropriate number of spirals needed to meet maximum required production. Cost of slurry splitters, fittings, and pipe are all included. Costs do not include transportation, sales tax, or discounts. The equation is applied to the following variable:
X = Maximum cubic yards of feed handled hourly by spiral concentrator.

The following capacities were used to calculate the base equation:

2 starts	–	2 yd^3/h.
10 starts	–	10 yd^3/h.
50 starts	–	50 yd^3/h.
100 starts	–	100 yd^3/h.

The above capacities are based on the following assumptions:
1. Rougher service.
2. 1.75 ton/h solids per start.
3. 3,400 lb/yd^3 feed solids.
4. 10% solids slurry density.
5. Gravity feed.

Base Equation:
Equipment capital cost: $Y_C = 3,357.70(X)^{0.999}$

The capital cost consists of 71% equipment purchase price, 13% construction labor and installation, and 16% construction materials.

Cleaner/Scavenger Service Factor:
If spirals are to be used for cleaner or scavenger functions, unit capacity will decrease. To account for additional equipment needed to maintain production, calculated capital cost must be multiplied by the following factor:

$F_C = 2.333$

Used Equipment Factor:
This factor accounts for reduced capital expenditure of purchasing equipment having over 10,000 h of previous service life:

$F_U = 0.654$

Processing equipment capital costs - Spiral concentrators

Total Cost:
Spiral concentrator capital cost = Y_C x F_C x F_U

This product is subsequently entered in the appropriate row on table 6 for final capital cost calculation.

72

Table Concentrators

Capital Cost Equation:

This equation furnishes the cost of purchasing and installing the appropriate size and number of tables needed to meet maximum required production. Cost includes associated drive motors, piping, and electrical hook-up. Equipment transportation, sales tax, and discounts are not accounted for. The equation is applied to the following variable:

X = Maximum cubic yards of feed handled hourly by table concentrator.

The following capacities were used to calculate the base equation:

18 ft^2	–	0.147 yd^3/h.
32 ft^2	–	0.442 yd^3/h.
80 ft^2	–	0.882 yd^3/h.
140 ft^2	–	1.471 yd^3/h.
240 ft^2	–	2.471 yd^3/h.

The above capacities are based on the following assumptions:
1. Cleaner service.
2. 3,400 lb/yd^3 feed solids.
3. 25% solids slurry density.
4. Gravity feed.

Base Equation:

Equipment capital cost: $Y_C = 20,598.06(X)^{0.643}$

The capital cost consists of 62% equipment purchase price, 12% construction labor and installation, and 26% construction materials.

Processing equipment capital costs - Table concentrators

Rougher/Coarse Factor:

If tables are to be used for rougher service, or a coarse feed, higher productivity will be realized. To account for reduction in equipment required to maintain production, the calculated capital cost must be multiplied by the following factor:

$F_R = 0.568$

Used Equipment Factor:

This factor accounts for reduced capital expenditure of purchasing equipment having over 10,000 h of previous service life:

$F_U = 0.596$

Total Cost:

Table concentrator capital cost = $Y_C \times F_R \times F_U$

This product is subsequently entered in the appropriate row on table 6 for final capital cost calculation.

73

Trommels

Capital Cost Equation:
This equation furnishes the cost of purchasing and installing the appropriate size trommels needed to meet maximum required production. Cost includes associated drive motors, piping, and electrical hook-up. Equipment transportation, sales tax, and discounts are not accounted for. The equation is applied to the following variable:
X = Maximum cubic yards of feed handled hourly by trommels.

The following capacities were used to calculate the base equation:

3.0 ft diam	–	40 yd^3/h.
3.5 ft diam	–	50 yd^3/h.
4.0 ft diam	–	85 yd^3/h.
4.5 ft diam	–	150 yd^3/h.
5.0 ft diam	–	250 yd^3/h.
5.5 ft diam	–	300 yd^3/h.
7.0 ft diam	–	500 yd^3/h.

The above capacities are based on the following assumptions:
1. Trommels are sectioned for scrubbing and sizing.
2. Gravity feed.
3. 2,300 lb/yd^3 feed density.

Base Equation:
Equipment capital cost: $Y_C = 7,176.21(X)^{0.559}$

The capital cost consists of 64% equipment purchase price, 26% construction and installation labaor, and 10% construction materials.
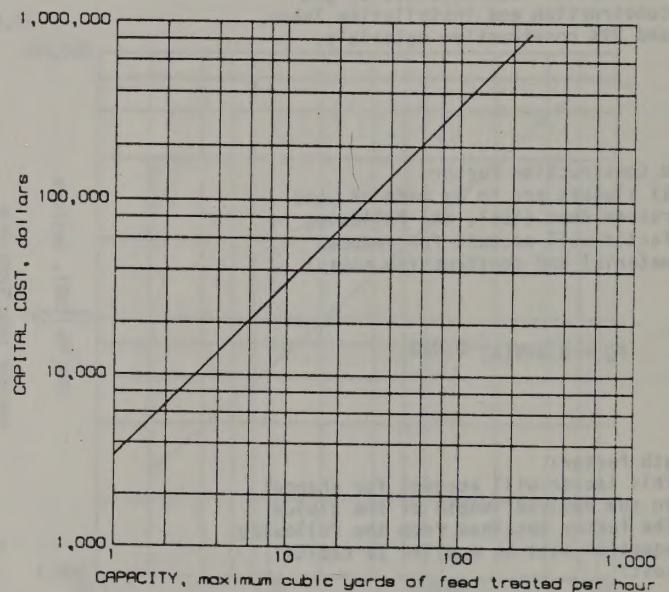
Used Equipment Factor:
This factor accounts for the reduced capital expenditure of purchasing equipment having over 10,000 h of previous service life:

$F_U = 0.516$

Total Cost:
Trommel capital cost = $Y_C \times F_U$

This product is subsequently entered in the appropriate row on table 6 for final capital cost calculation.

Processing equipment capital costs - Trommels

74

Capital Cost Equation:
   This equation furnishes the cost of purchasing and installing the appropriate size and number of vibrating screens needed to meet maximum required production. Cost includes installation and electrical hook-up of both the screens and the associated drive motors. Equipment transportation, sales tax, and discounts have not been taken into account. The equation is applied to the following variable:
   X = Maximum cubic yards of feed handled hourly by vibrating screens.

The following capacities were used to calculate the base equation:
   30 ft^2 screen surface   –   47 yd^3/h.
   56 ft^2 screen surface   –   87 yd^3/h.
   60 ft^2 screen surface   –   93 yd^3/h.
   96 ft^2 screen surface   –   150 yd^3/h.
   140 ft^2 screen surface –   218 yd^3/h.

The above capacities are based on the following assumptions:
   1. An average of 0.642 ft^2 of screen is required for every cubic yard of hourly capacity.
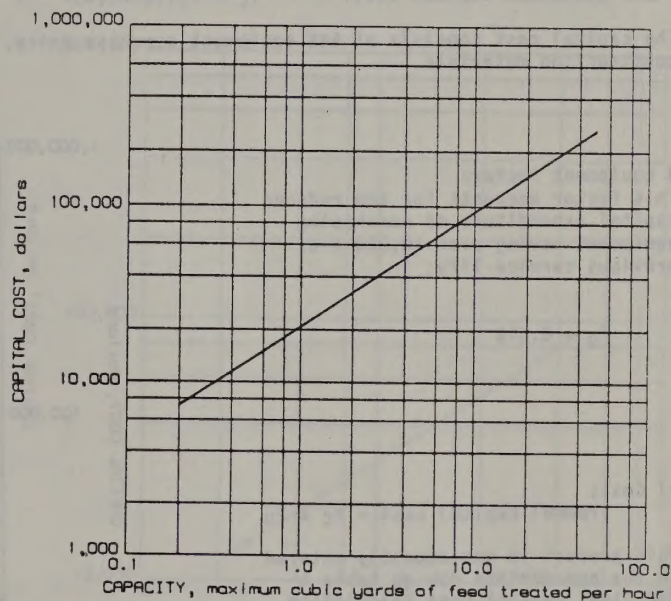   2. 3,120 lb/yd^3 feed solids.
   3. Gravity feed.

Base Equation:
   Equipment capital cost: $Y_C = 1,870.20(X)^{0.631}$

The capital cost consists of 75% equipment purchase price, 10% construction and installation labor, and 15% construction materials.

Capacity Factor:
   If anticipated screen capacity is other than 0.624 ft^2/yd^3 of hourly feed capacity, the calculated capital cost must be multiplied by the following factor:

   $F_C = 1.322(C)^{0.629}$

   where C = Anticipated capacity in square feet per cubic yard of hourly feed.

   This will account for the increase or reduction in equipment size required to maintain production.

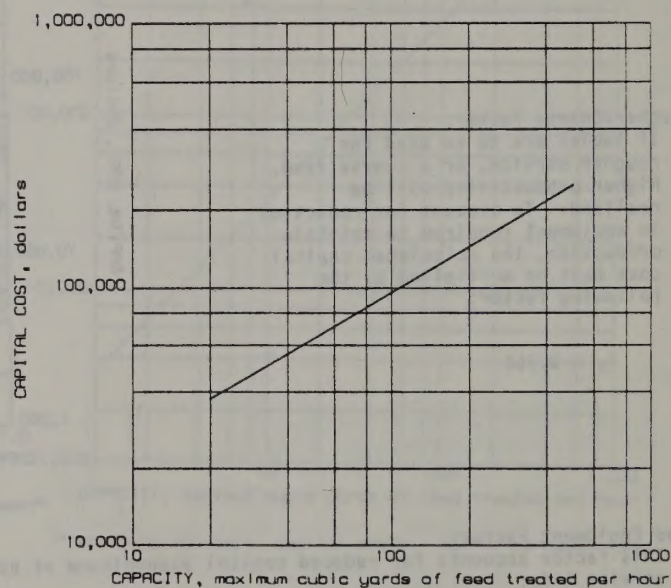Processing equipment capital costs - Vibrating screens

Used Equipment Factor:
   This factor accounts for reduced capital expenditure of purchasing equipment having over 10,000 h of previous service life:

   $F_U = 0.565$

Total Cost:
   Vibrating screen capital cost = $Y_C \times F_C \times F_U$

This product is subsequently entered in the appropriate row on table 6 for final capital cost calculation.

Buildings

Capital Cost Equation:
This equation provides the cost of materials and construction for any buildings needed at the site. These may include storage sheds, shops, or mill buildings. Costs do not include sales tax, material transportation, or discounts. A separate cost must be calculated for each building, and the equation is applied to the following variable:
X = Estimated floor area in square feet.

Building costs are based on the following assumptions:
1. Average quality temporary structures.
2. Steel frame with metal siding and roofing.
3. Concrete perimeter foundations with wood floors.
4. Electicity and lighting provided.

Base Equation:
Capital cost: $Y_C = 34.09(X)^{0.907}$

The capital cost consists of 34% construction labor, 41% construction materials, and 25% equipment.

Cement Floor Factor:
If a cement floor is required, the cost calculated from the base equation must be multiplied by the factor obtained from the following equation:

$$F_C = 1.035(X)^{0.008}$$

Plumbing Factor:
If plumbing is required, the following factor must be applied to the total capital cost:

$$F_p = 1.013(X)^{0.002}$$
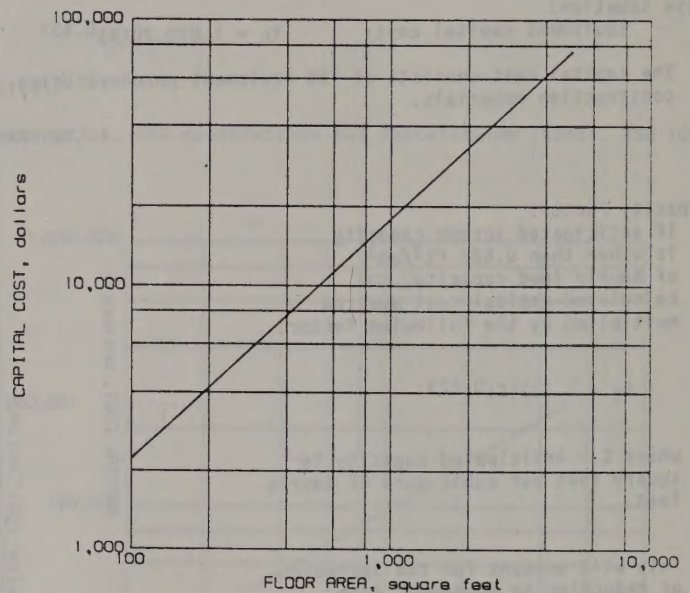
Supplemental capital costs - Buildings

Foundation Factor:
If a concrete foundation and wood floor are not needed, multiply the capital cost by the factor obtained from the following equation:

$$F_F = 0.640(X)^{0.026}$$

This will account for the cost of wood blocks and sills for the foundation.

Total Cost:
Building capital cost = $Y_C \times F_C \times F_p \times F_F$

This product is subsequently entered in the appropriate row on table 6 for final capital cost calculation.

Employee Housing

Capital Cost Equation:
Costs of purchasing, outfitting, and installing trailers for workers living at the minesite are provided by this equation. Costs are based on fair quality single-wide trailers capable of meeting minimum building code requirements. Costs do not include sales tax, equipment transportation, or discounts. The equation is applied to the following variable:

X = Average cubic yards of overburden and pay gravel handled hourly.

The following capacities were used to calculate the base equation:

25 yd^3/h	–	3.1 workers.
50 yd^3/h	–	4.2 workers.
150 yd^3/h	–	6.6 workers.
400 yd^3 h	–	9.9 workers.

The above capacities are based on the following assumptions:
1. Average work force for placer mines in the western United States (including Alaska).
2. Two workers per trailer.
3. Trailers contain cooking facilities.

Base Equation:
Capital cost: $Y_C = 7,002.51(X)^{0.418}$

The capital cost consists of 90% equipment purchase price, 7% construction and installation labor, and 3% construction materials.
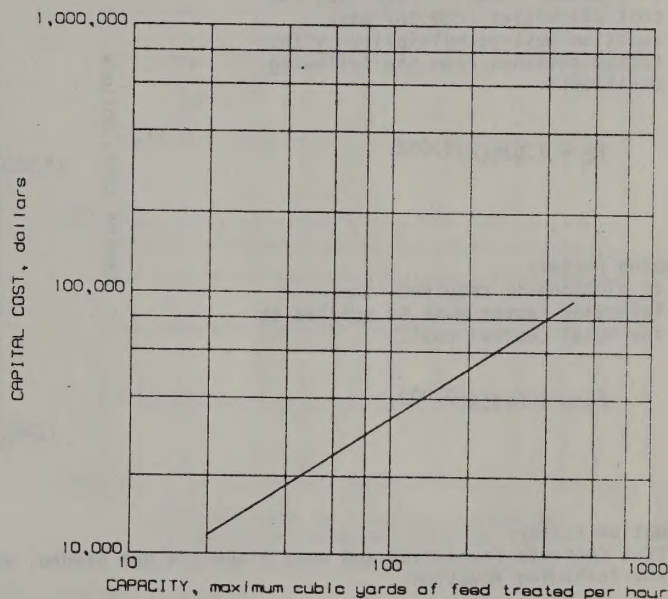
Used Equipment Factor:
This factor accounts for the reduced expense of purchasing used trailers. The adjusted cost is obtained by multiplying the calculated capital cost by the following factor:

$F_U = 0.631$

CAPACITY, average loose cubic yards pay gravel plus overburden mined per hour

Supplemental capital costs - Employee housing

Work Force Factor:
The equation used to compute manpower for capital cost estimation is:

Work force = $0.822(X)^{0.415}$

If the work force for the operation under evaluation is known, and is different than that calculated from the above equation, the correct capital cost may be obtained from the following equation:

Y_C = (Number of Workers) X 8,608.18

Total Cost:
Employee housing capital cost = Y_C x F_U

This product is subsequently entered in the appropriate row on table 6 for final capital cost calculation.

77
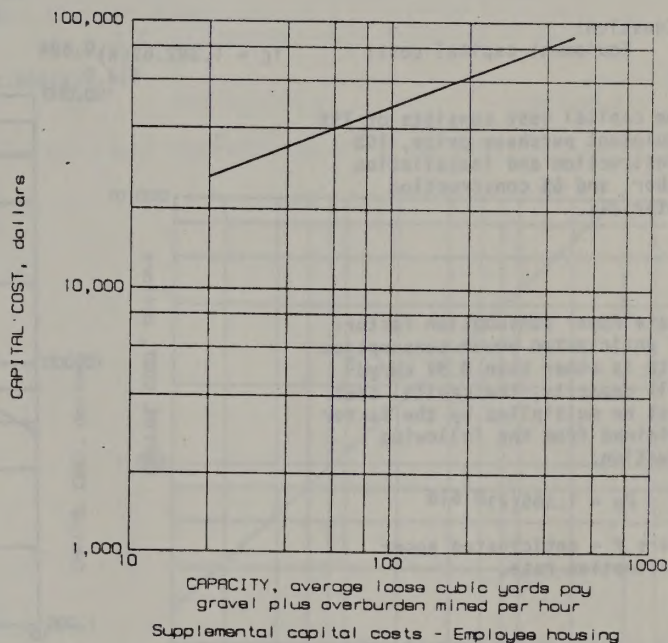
Capital Cost Equation:
 This equation provides the cost of purchasing and installing the appropriate size generator required to meet maximum production. Cost includes installation and connection through the fuse box, and allows for mill, mine, camp, and ancillary function power consumption. Costs do not include equipment transportation, sales tax, or discounts. The equation is applied to the following variable:
 X = Maximum cubic yards of mill feed handled per hour.

The following capacities were used to calculate the base equation:

10-kW generator	–	10 yd³/h.
30-kW generator	–	40 yd³/h.
45-kW generator	–	75 yd³/h.
75-kW generator	–	125 yd³/h.
125-kW generator	–	200 yd³/h.
250-kW generator	–	400 yd³/h.

The above capacities are based on the assumption that 0.57 kW are needed for every cubic yard of mill capacity. This is average for a mine with a basic plant containing trommels, conveyors, mechanical gravity separation devices (jigs or tables), and other necessary ancillary equipment. In all cases, a slightly higher rated generator has been selected for costing purposes to account for demand surges and miscellaneous electrical consumption, such as camp electricity. A factor is provided below for operations with power consumption rates other than 0.57 kW/yd³.

Base Equation:
 Equipment capital cost: $Y_C = 1,382.65(X)^{0.604}$

The capital cost consists of 75% equipment purchase price, 19% construction and installation labor, and 6% construction materials.

Alternate Power Consumption Factor:
 If anticipated power consumption rate is other than 0.57 kW/yd³ mill capacity, the capital cost must be multiplied by the factor obtained from the following equation:

 $F_P = 1.365(P)^{0.618}$

 where P = anticipated power consumption rate.

CAPITAL COST, dollars

MILL CAPACITY, maximum cubic yards of feed treated per hour
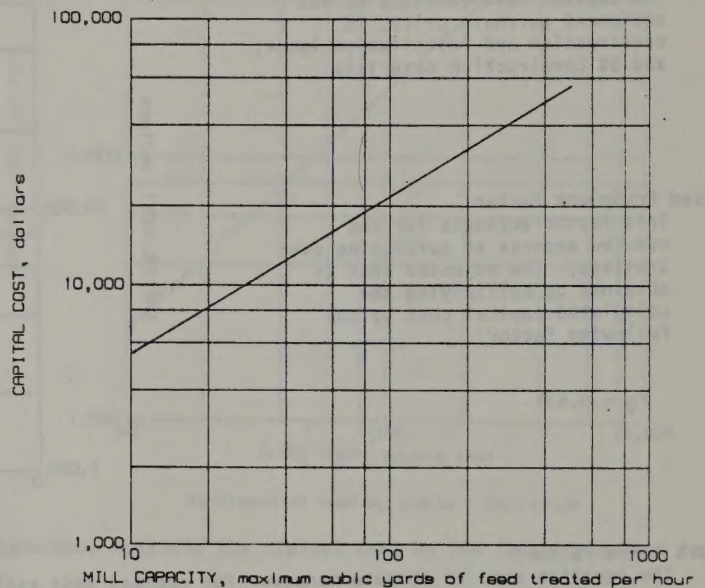
Supplemental capital costs - Generators

Used Equipment Factor:
 This factor accounts for reduced capital expenditure of purchasing equipment having over 10,000 h of previous service life:

 $F_U = 0.481$

Total Cost:
 Generator capital cost $= Y_C \times F_P \times F_U$

This product is subsequently entered in the appropriate row on table 6 for final capital cost calculation.

Capital Cost Equation:

This equation furnishes the cost of purchasing and installing the appropriate size of pump needed for each particular function (i.e. providing fresh mill water, recirculating spent water through settling ponds, etc.). If more than one pump is required, a separate cost must be calculated for each installation. Guidelines for pump requirements are listed in the text portion of this manual. In general, however, at least one pump will be required if water is recycled through settling ponds. Costs of diesel driven centrifugal pumps, PVC pipe, and pump and pipe installation labor are all considered. Costs of equipment transportation, sales tax, and discounts are not included. The equation is applied to the following variable:

X = Maximum gallons per minute of water handled.

The following capacities were used to calculate the base equation:

0.50 hp pump	–	50 gpm.
2.00 hp pump	–	200 gpm.
5.25 hp pump	–	500 gpm.
10.50 hp pump	–	1,000 gpm.
18.50 hp pump	–	1,750 gpm.
37.00 hp pump	–	3,500 gpm.

The above capacities are based on the following assumptions:
1. Total head of 25 ft.
2. Diesel powered pumps.
3. Abrasion-resistant steel construction.
4. Total engine-pump efficiency of 60%.

Base Equation:

Equipment capital cost: $Y_C = 63.909(X)^{0.618}$

The capital cost consists of 70% equipment purchase price, 22% construction materials, and 8% construction and installation labor

Head Factor:

If total pumping head is other than 25 ft, the factor calculated from the following equation will correct for changes in pump size requirements. The product of this factor and the original cost will provide the appropriate figure:

$F_H = 0.125(H)^{0.637}$

where H = total pumping head.

Used Equipment Factor:

This factor accounts for reduced capital expenditure of purchasing equipment having over 10,000 h of previous service life:

$F_U = 0.615$

Supplemental capital costs – Pumps

Total Cost:

Pump capital cost = $Y_C \times F_H \times F_U$

This product is subsequently entered in the appropriate row on table 6 for final capital cost calculation.
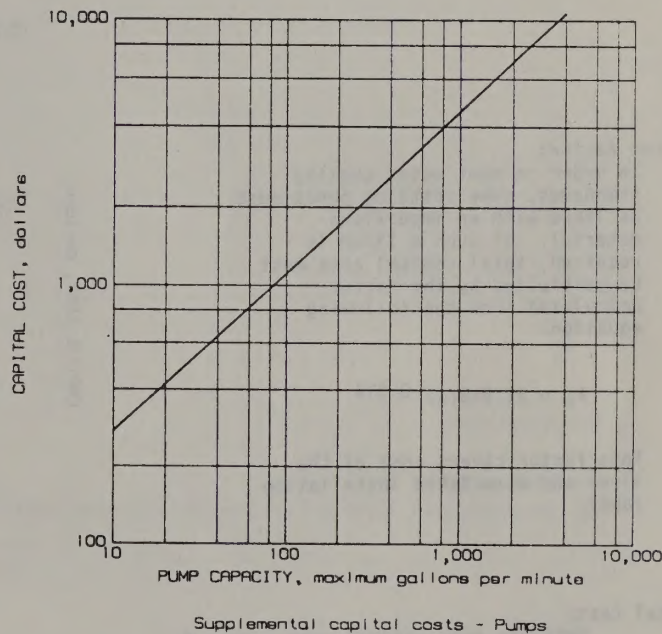
Settling Ponds

Capital Cost Equation:

This equation furnishes the cost of settling ponds for waste water treatment. Costs of labor and equipment operation for site selection, size determination, rough surveying, excavation, ditching, grading, and placement of sized gravel are all included. The equation is applied to the following variable:

X = Maximum mill water consumption in gallons per minute.

If the water consumption rate is not known, one can be estimated from the following equation:

$$X = 94.089(Y)^{0.546}$$

where Y = maximum cubic yards of mill feed handled per hour.

The following capacities were used to calculate the base equation:

400 gpm	–	1,426 yd^3 liquid capacity.
600 gpm	–	2,139 yd^3 liquid capacity.
900 gpm	–	3,208 yd^3 liquid capacity.
1,400 gpm	–	4,991 yd^3 liquid capacity.

The above capacities are based on the following assumptions:
1. Pond located in mined-out area.
2. Excavated by bulldozer.
3. Capable of holding 12 h of waste water produced by mill.
4. Based on jig plant water consumption rate.

Base Equation:

Capital cost: $Y_C = 3.982(X)^{0.952}$

The capital cost consists of 75% construction labor, 13% fuel and lubrication, and 12% equipment parts.

Liner Factor:

In order to meet water quality standards, some settling ponds must be lined with an impervious material. If such a liner is required, total capital cost must be multiplied by the factor calculated from the following equation:

$$F_L = 27.968(X)^{-0.314}$$

This factor covers cost of the liner and associated installation labor.

Supplemental capital costs – Settling ponds

Total Cost:

Settling pond capital cost = $Y_C \times F_L$

This product is subsequently entered in the appropriate row on table 6 for final capital cost calculation.
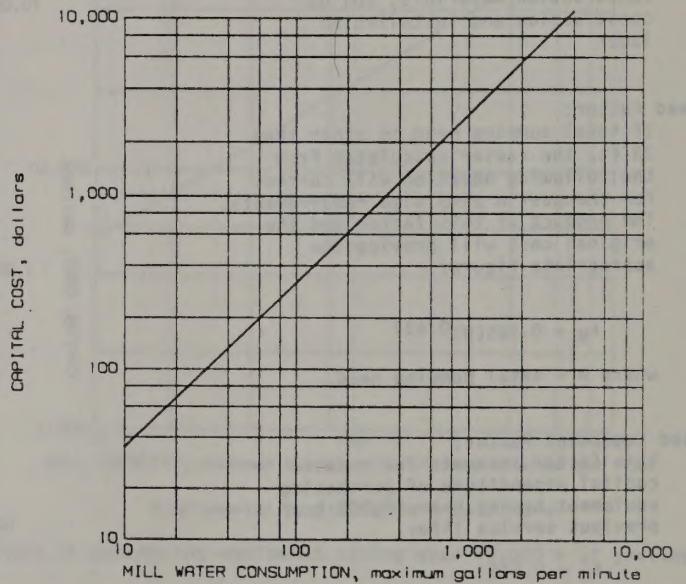
TABLE 6. – Capital cost summary form

Item	Cost
Exploration:	
Method I cost...	$
Method II cost..	
Development:	
Access roads..	
Clearing..	
Overburden removal:	
Bulldozers..	
Draglines...	
Front-end loaders...	
Rear-dump trucks..	
Scrapers..	
Mine Equipment:	
Backhoes..	
Bulldozers..	
Draglines...	
Front-end loaders...	
Rear-dump trucks..	
Scrapers..	
Processing Equipment:	
Conveyors...	
Feed hoppers..	
Jig concentrators...	
Sluice..	
Spiral concentrators......................................	
Table concentrators.......................................	
Trommels..	
Vibrating screens...	
Supplemental:	
Buildings...	
Camp..	
Generators..	
Pumps...	
Settling ponds..	
Subtotal..	
Contingency...	
Total...	

Overburden

Bulldozers

Operating Cost Equations:
These equations provide the cost of excavating and relocating overburden using bulldozers. Costs are reported in dollars per LCY of overburden handled. The equations are applied to the following variable:
X = Maximum LCY of pay gravel, overburden, and tails moved hourly by bulldozer.

The base equations assume the following:
1. No ripping.
2. 50 ft cutting distance.
3. 50 min/h efficiency.
4. 300 ft dozing distance.
5. Average operator ability.
6. Nearly level gradient.

Base Equations:

Equipment operating cost: $Y_E = 0.993(X)^{-0.430}$

Labor operating cost: $Y_L = 14.01(X)^{-0.945}$

Equipment operating costs average 47% parts and 53% fuel and lubrication. Labor operating costs average 86% operator labor and 14% repair labor.

Distance Factor:
If the average dozing distance is other than 300 ft, the factor obtained from the following equation must be applied to total cost per LCY:

$F_D = 0.00581(Distance)^{0.904}$

Gradient Factor:
If the average gradient is other than level, the factor obtained from the following equation must be applied to the total cost per LCY:

$F_G = 1.041e^{[0.015(\% \ gradient)]}$.

Ripping Factor:
If ripping is required, total operating cost must be multiplied by the following factor:

$F_R = 1.595$

This will account for the reduced productivity associated with ripping.

Overburden removal operating costs - Bulldozers

Used Equipment Factor:
These factors account for added operating expenses accrued by equipment having over 10,000 h of previous service life. The respective equipment and labor portions of the base operating costs must be multiplied by the factors obtained from the following equations:

Equipment factor: $U_e = 1.206(X)^{-0.013}$

Labor factor: $U_l = 0.967(X)^{0.015}$

Digging Difficulty Factor:
Parameters given in the discussion on Site Adjustment Factors in section 1 should be used to determine if a digging difficulty factor is required. If so, one of the following should be applied to total cost per LCY:

F_H = Easy digging   = 0.830
       Medium digging   = 1.000
       Medium-Hard digging = 1.250
       Hard digging   = 1.670

Total Cost:
Cost/LCY overburden = $[Y_E(U_e) + Y_L(U_l)] \times F_D \times F_G \times F_H \times F_R$

The above total cost per LCY must then be multiplied by the total yearly amount of <u>overburden</u> handled by bulldozer. This product is subsequently entered in the appropriate row on table 7 for final operating cost calculation.

82

Draglines

Operating Cost Equations:
These equations provide the cost of excavating overburden using draglines. Costs are reported in dollars per LCY of overburden handled. The equations are applied to the following variable:
X = Maximum LCY of pay gravel, overburden, and tails moved hourly by dragline.

The base curves assume the following:
1. 0.90 bucket efficiency.
2. Full hoist.
3. 90° swing angle.
4. Average operator ability.

Base Equations:
Equipment operating cost: $Y_E = 1.984(X)^{-0.390}$

Labor operating cost: $Y_L = 12.19(X)^{-0.888}$

Equipment operating costs consist of 67% parts and 33% fuel and lubrication. Labor operating costs consist of 78% operator labor and 22% repair labor.

Swing Angle Factor:
If average swing angle is other than 90°, the factor obtained from the following equation must be applied to the total cost per LCY:
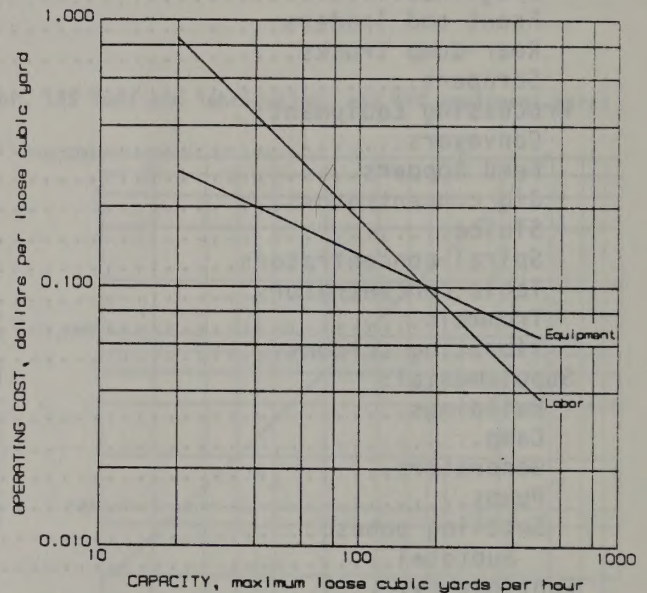
$$F_S = 0.304(\text{swing angle})^{0.269}$$

Used Equipment Factor:
These factors account for added operating expenses accrued by equipment having over 10,000 h of previous service life. The respective equipment and labor portions of the base operating costs must be multiplied by the factors obtained from the following equations:

Equipment factor: $U_e = 1.162(X)^{-0.017}$

Labor factor: $U_l = 0.989(X)^{0.006}$

Overburden removal operating costs - Draglines

Total Cost:
Cost/LCY overburden = $[Y_E(U_e) + Y_L(U_l)] \times F_S$

The above total cost per LCY must then be multiplied by the total yearly amount of <u>overburden</u> handled by dragline. This product is subsequently entered in the appropriate row on table 7 for final operating cost calculation.

Front-End Loaders

Operating Cost Equations:
These equations provide the cost of relocating overburden using wheel front-end loaders. Costs are reported in dollars per LCY of overburden handled. The equations are applied to the following variable:

X = Maximum LCY of pay gravel, overburden, and tails moved hourly by front-end loader.

The base equations assume the following:
1. 500 ft haul distance.
2. 2% rolling resistance, nearly level gradient.
3. Inconsistent operation.
4. Wheel-type loader.

Base Equations:

Equipment operating cost: $Y_E = 0.407(X)^{-0.225}$

Labor operating cost: $Y_L = 13.07(X)^{-0.936}$

Equipment operating costs average 22% parts, 46% fuel and lubrication, and 32% tires. Labor operating costs average 90% operator labor and 10% repair labor.

Distance Factor:
If average haul distance is other than 500 ft, the factor obtained from the following equation must be applied to the total cost per LCY:

$$F_D = 0.023(distance)^{0.616}$$

Gradient Factor:
If total gradient (gradient plus rolling resistance) is other than 2%, the factor obtained from the following equation must be applied to the total cost per LCY:

$$F_G = 0.877e^{[0.046(\% \ gradient)]}$$

Overburden removal operating costs - Front-end loaders

Used Equipment Factor:
These factors account for added operating expenses accrued by equipment having over 10,000 h of previous service life. The respective equipment and labor portions of the base operating costs must be multiplied by the factors obtained from the following equations:
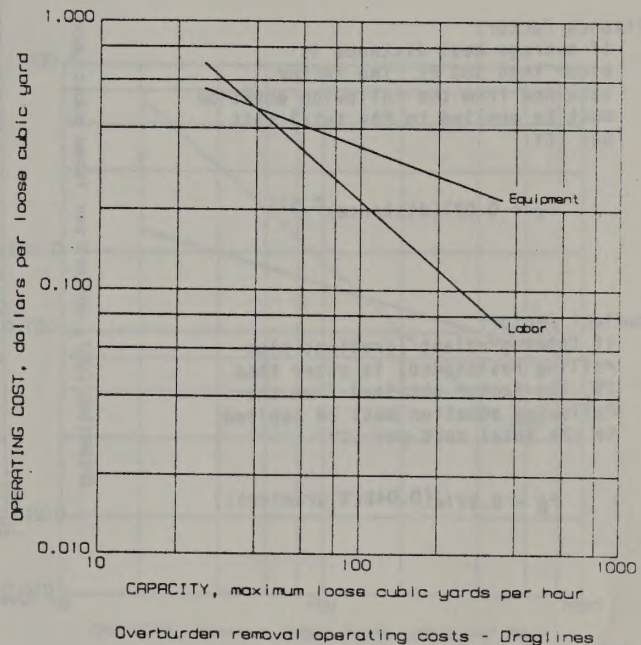
Equipment factor: $U_e = 1.162(X)^{-0.017}$

Labor factor: $U_1 = 0.989(X)^{0.006}$

Track-Type Loader Factor:
If track-type loaders are used, the following factors must be applied to the total cost obtained from the base equations:

Equipment factor: $T_e = 1.378$

Labor factor: $T_1 = 1.073$

Total Cost:
Cost/LCY overburden = $[Y_E(U_e)(T_e) + Y_L(U_1)(T_1)] \times F_D \times F_G$

The above total cost per LCY must then be multiplied by the total yearly amount of <u>overburden</u> handled by front-end loader. This product is subsequently entered in the appropriate row on table 7 for final operating cost calculation.

84

Rear-Dump Trucks

Operating Cost Equations:

These equations provide the cost of hauling overburden using rear-dump trucks. Costs are reported in dollars per LCY of overburden handled. The equations are applied to the following variable:

X = Maximum LCY of pay gravel, overburden, and tails moved hourly by rear dump truck.

The base equations assume the following:
1. 2,500 ft haul distance.
2. 4 loader cycles to fill.
3. 50 min/h efficiency.
4. Average operator ability.
5. Nearly level gradient.

Base Equations:

Equipment operating cost: $Y_E = 0.602(X)^{-0.296}$

Labor operating cost: $Y_L = 11.34(X)^{-0.891}$

Equipment operating costs consist of 28% parts, 58% fuel and lubrication, and 14% tires. Labor operating costs consist of 82% operator labor and 18% repair labor.
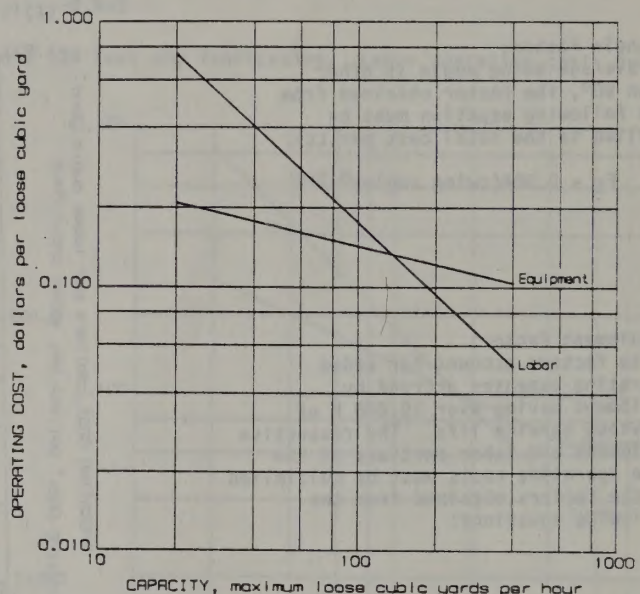
Distance Factor:

If average haul distance is other than 2,500 ft, the factor obtained from the following equation must be applied to total cost per LCY:

$F_D = 0.093(distance)^{0.311}$

Gradient Factor:

If total gradient (gradient plus rolling resistance) is other than 2%, the factor obtained from the following equation must be applied to total cost per LCY:

$F_G = 0.907e^{[0.049(\% \text{ gradient})]}$

Overburden removal operating costs - Rear-dump trucks

Used Equipment Factor:

These factors account for added operating expenses accrued by equipment having over 10,000 h of previous service life. The respective equipment and labor portions of the base operating costs must be multiplied by the factors obtained from the following equations:

Equipment factor: $U_e = 0.984(X)^{-0.016}$

Labor factor: $U_l = 0.943(X)^{0.021}$

Total Cost:

Cost/LCY overburden = $[Y_E(U_e) + Y_L(U_l)] \times F_D \times F_G$

The above total cost per LCY must then be multiplied by the total yearly amount of <u>overburden</u> handled by truck. This product is subsequently entered in the appropriate row on table 7 for final operating cost calculation.

Scrapers

Operating Cost Equations:

These equations provide the cost of excavating and hauling overburden using scrapers. Costs are reported in dollars per LCY of overburden handled. The equations are applied to the following variable:

   X = Maximum LCY of pay gravel, overburden, and tails moved hourly by scraper.

The base curves assume the following:
1. Standard scrapers.
2. 6% rolling resistance, nearly level gradient.
3. 50 min/h efficiency.
4. 1,000 ft haul distance.
5. Average operator ability.

Base Equations:

Equipment operating cost: $Y_E = 0.325(X)^{-0.210}$

Labor Operating Cost: $Y_L = 12.01(X)^{-0.930}$

Equipment operating costs consist of 48% fuel and lubrication, 34% tires, and 18% parts. Labor operating costs consist of 88% operator labor and 12% repair labor.
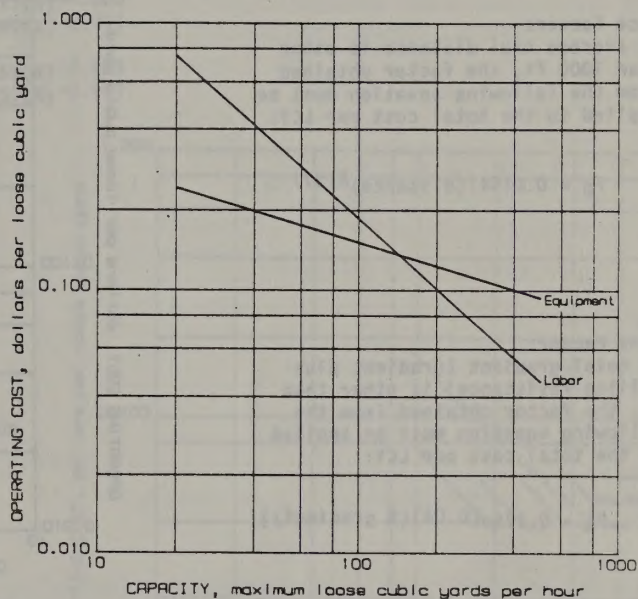
Distance Factor:

If average haul distance is other than 1000 ft, the factor obtained from the following equation must be applied to the total cost per LCY:

$$F_D = 0.01947(distance)^{0.577}$$

Gradient Factor:

If total gradient (gradient plus rolling resistance) is other than 6%, the factor obtained from the following equation must be applied to the total cost per LCY:

$$F_G = 0.776e^{[0.047(\% \; gradient)]}$$

Overburden removal operating costs - Scrapers

Used Equipment Factor:

These factors account for added operating expenses accrued by equipment having over 10,000 h of previous service life. The respective equipment and labor portions of the base operating costs must be multiplied by the factors obtained from the following equations:

Equipment factor: $U_e = 1.096(X)^{-0.006}$

Labor factor: $U_l = 0.845(X)^{0.034}$

Total Cost:

Cost/LCY overburden = $[Y_E(U_e) + Y_L(U_l)] \times F_D \times F_G$

The above total cost per LCY must then be multiplied by the total yearly amount of <u>overburden</u> handled by scraper. This product is subsequently entered in the appropriate row on table 7 for final operating cost calculation.

Mining

Backhoes

Operating Cost Equations:

These equations provide the cost of excavating pay gravel using backhoes. Costs are reported in dollars per LCY of pay gravel handled. The equations are applied to the following variable:

X = Maximum LCY of pay gravel moved hourly by backhoe.

The base equations assume the following:
1. Easy digging difficulty.
2. $60°$ to $90°$ swing angle.
3. Up to 50% of maximum digging depth.
4. Average operator ability.
5. No obstructions (boulders, tree roots, etc.).

Base Equations:

95 – 200 LCY/h
Equipment operating cost: $Y_E = 8.360(X)^{-1.019}$
Labor operating cost: $Y_L = 17.53(X)^{-1.009}$

175 – 275 LCY/h
Equipment operating cost: $Y_E = 11.44(X)^{-1.021}$
Labor operating cost: $Y_L = 17.25(X)^{-1.000}$

250 – 375 LCY/h
Equipment operating cost: $Y_E = 15.17(X)^{-1.003}$
Labor operating cost: $Y_L = 19.97(X)^{-1.017}$

350 – 475 LCY/h
Equipment operating cost: $Y_E = 22.59(X)^{-0.995}$
Labor operating cost: $Y_L = 16.55(X)^{-0.977}$

Equipment operating costs consist of 38% parts, and 62% fuel and lubrication. Labor operating costs consist of 88% operator labor and 12% repair labor.

Digging Depth Factor:
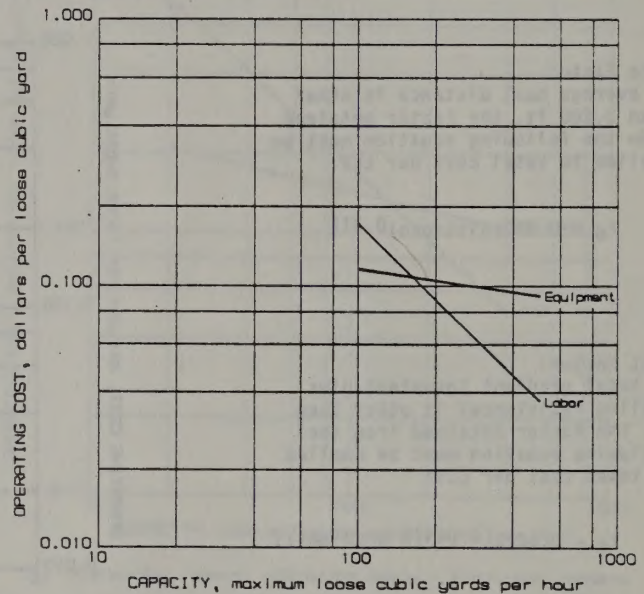
If average digging depth is other than 50% of maximum, the factor obtained from the following equation must be applied to the total cost per LCY of pay gravel:

$$F_D = 0.09194(\% \text{ of maximum digging depth})^{0.608}.$$

Used Equipment Factor:

These factors account for added operating expenses accrued by equipment having over 10,000 h of previous service life. The respective equipment and labor portions of the base operating costs must be multiplied by the factors obtained from the following equations:

Equipment factor: $U_e = 1.078(X)^{-0.003}$

Labor factor: $U_1 = 0.918(X)^{0.021}$

Mining operating costs - Backhoes

Digging Difficulty Factor:

Parameters given in the discussion on Site Adjustment Factors in section 1 should be used to determine if a digging difficulty factor is required. If so, one of the following should be applied to total cost per LCY of pay gravel:

F_H = Easy digging	=	1.000
Medium digging	=	1.250
Medium-Hard digging	=	1.500
Hard digging	=	1.886

Total Cost:

$$\text{Cost/LCY pay gravel} = [Y_E(U_e) + Y_L(U_1)] \times F_D \times F_H$$

The above total cost per LCY must then be multiplied by the total yearly amount of <u>pay gravel</u> handled by backhoe. This product is subsequently entered in the appropriate row on table 7 for final operating cost calculation.
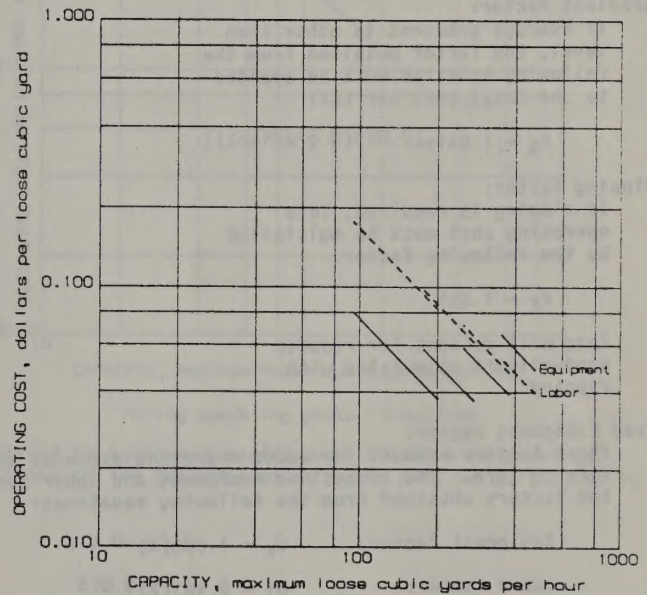
Bulldozers

Operating Cost Equations:
These equations provide the cost of excavating and relocating pay gravel using bulldozers. Costs are reported in dollars per LCY of pay gravel handled. The equations are applied to the following variable:

X = Maximum LCY of pay gravel, overburden, and tails moved hourly by bulldozer.

The base equations assume the following:
1. No ripping.
2. 50 ft cutting distance.
3. 50 min/h efficiency.
4. 300 ft dozing distance.
5. Average operator ability.
6. Nearly level gradient.

Base Equations:
Equipment operating cost: $Y_E = 0.993(X)^{-0.430}$

Labor operating cost: $Y_L = 14.01(X)^{-0.945}$

Equipment operating costs average 47% parts and 53% fuel and lubrication. Labor operating costs average 86% operator labor and 14% repair labor.

Distance Factor:
If average dozing distance is other than 300 ft, the factor obtained from the following equation must be applied to the total cost per LCY:

$$F_D = 0.00581(distance)^{0.904}$$

Gradient Factor:
If average gradient is other than level, the factor obtained from the following equation must be applied to the total cost per LCY:

$$F_G = 1.041e^{[0.015(\% \text{ gradient})]}$$

Ripping Factor:
If ripping is required, total operating cost must be multiplied by the following factor:

$$F_R = 1.595$$

This will account for reduced productivity associated with ripping.

Mining operating costs - Bulldozers

Used Equipment Factor:
These factors account for added operating expenses accrued by equipment having over 10,000 h of previous service life. The respective equipment and labor portions of the base operating costs must be multiplied by the factors obtained from the following equations:

Equipment factor: $U_e = 1.206(X)^{-0.013}$

Labor factor: $U_l = 0.967(X)^{0.015}$

Digging Difficulty Factor:
Parameters given in the discussion on Site Adjustment Factors in section 1 should be used to determine if a digging difficulty factor is required. If so, one of the following should be applied to total cost per LCY:

F_H = Easy digging = 0.830
Medium digging = 1.000
Medium-Hard digging = 1.250
Hard digging = 1.670

Total Cost:
Cost/LCY pay gravel = $[Y_E(U_e) + Y_L(U_l)] \times F_D \times F_G \times F_H \times F_R$

The above total cost per LCY must then be multiplied by total yearly amount of _pay gravel_ handled by bulldozer. This product is subsequently entered in the appropriate row on table 7 for final operating cost calculation.

88
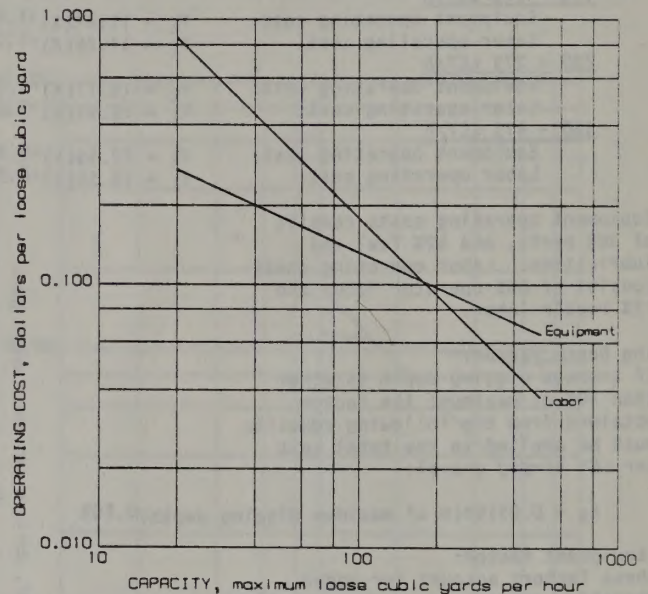
Operating Cost Equations:

These equations provide the cost of excavating pay gravel using draglines. Costs are reported in dollars per LCY of pay gravel handled. The equations are applied to the following variable:

X = Maximum LCY of pay gravel, overburden, and tails moved hourly by dragline.

The base curves assume the following:
1. 0.90 bucket efficiency.
2. Full hoist.
3. $90°$ swing angle.
4. Average operator ability.

Base Equations:

Equipment operating cost: $\qquad Y_E = 1.984(X)^{-0.390}$

Labor operating cost: $\qquad Y_L = 12.19(X)^{-0.888}$

Equipment operating costs consist of 67% parts and 33% fuel and lubrication. Labor operating costs consist of 78% operator labor and 22% repair labor.

Swing Angle Factor:

If the average swing angle is other than $90°$, the factor obtained from the following equation must be applied to total cost per LCY:

$$F_A = 0.304(\text{swing angle})^{0.269}$$
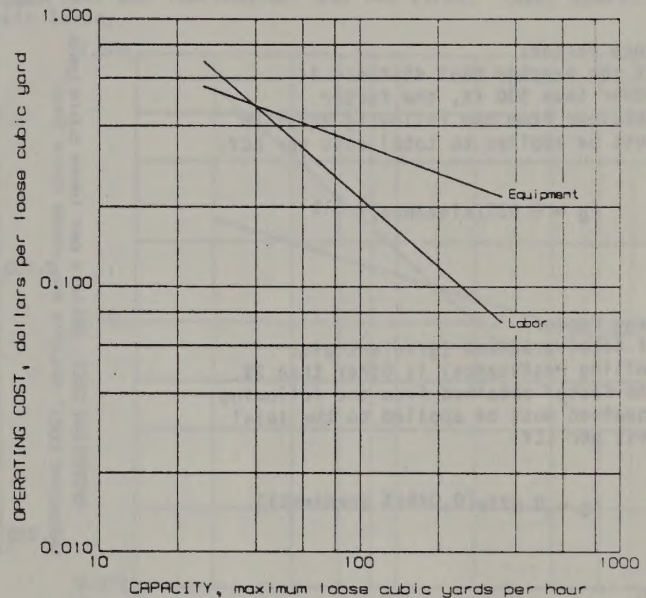
Mining operating costs - Draglines

Used Equipment Factor:

These factors account for added operating expenses accrued by equipment having over 10,000 h of previous service life. The respective equipment and labor portions of the base operating costs must be multiplied by the factors obtained from the following equations:

Equipment factor: $\qquad U_e = 1.162(X)^{-0.017}$

Labor factor: $\qquad U_l = 0.989(X)^{0.006}$

Total Cost:

Cost/LCY pay gravel = $[Y_E(U_e) + Y_L(U_l)] \times F_S$

The above total cost per LCY must then be multiplied by the total yearly amount of pay gravel handled by dragline. This product is subsequently entered in the appropriate row on table 7 for final operating cost calculation.

89

Front-End Loaders

Operating Cost Equations:
These equations provide the cost of hauling pay gravel using wheel front-end loaders. Costs are reported in dollars per LCY of pay gravel handled. The equations are applied to the following variable:

X = Maximum LCY of pay gravel, overburden, and tails moved hourly by front-end loaders.

The base equations assume the following:
1. 500 ft haul distance.
2. 2% rolling resistance, nearly level gradient.
3. Inconsistent operation.
4. Wheel-type loader.

Base Equations:

Equipment operating cost: $Y_E = 0.407(X)^{-0.225}$

Labor operating cost: $Y_L = 13.07(X)^{-0.936}$

Equipment operating costs average 22% parts, 46% fuel and lubrication, and 32% tires. Labor operating costs average 90% operator labor and 10% repair labor.

Distance Factor:
If the average haul distance is other than 500 ft, the factor obtained from the following equation must be applied to total cost per LCY:

$$F_D = 0.023(distance)^{0.616}$$

Gradient Factor:
If total gradient (gradient plus rolling resistance) is other than 2%, the factor obtained from the following equation must be applied to the total cost per LCY:

$$F_G = 0.877e^{[0.046(\% \text{ gradient})]}$$

Mining operating costs - Front-end loaders

Used Equipment Factor:
These factors account for added operating expenses accrued by equipment having over 10,000 h of previous service life. The respective equipment and labor portions of the base operating costs must be multiplied by factors obtained from the following equations:

Equipment factor: $U_e = 1.162(X)^{-0.017}$

Labor factor: $U_l = 0.989(X)^{0.006}$

Track-Type Loader Factor:
If track-type loaders are used, the following factors must be applied to total cost obtained from the base equations:

Equipment factor: $T_e = 1.378$

Labor factor: $T_l = 1.073$

Total Cost:
Cost/LCY pay gravel = $[Y_E(U_e)(T_e) + Y_L(U_l)(T_l)] \times F_D \times F_G$

The above total cost per LCY must then be multiplied by total yearly amount of <u>pay gravel</u> handled by front-end loader. This product is subsequently entered in the appropriate row on table 7 for final operating cost calculation.

90

Rear-Dump Trucks

Operating Cost Equations:
   These equations provide the cost of hauling pay gravel using rear-dump trucks. Costs are reported in dollars
   per LCY of pay gravel. The equations are applied to the following variable:
      X = Maximum LCY of pay gravel, overburden, and tails moved hourly by rear dump truck.

   The base equations assume the following:
      1. 2,500 ft hual distance.
      2. 4 loader cycles to fill.
      3. 50 min/h efficiency.
      4. Average operator ability.
      5. 2% rolling resistance, nearly level gradient.

Base Equation:
      Equipment operating cost: $Y_E = 0.602(X)^{-0.296}$

      Labor operating cost: $Y_L = 11.34(X)^{-0.891}$

   Equipment operating costs consist of 28% parts, 58% fuel and lubrication, and 14% tires. Labor operating
   costs consist of 82% operator labor and 18% repair labor.

Distance Factor:
   If average haul distance is other
   than 2,500 ft, the factor obtained
   from the following equation must be
   applied to total cost per LCY:

      $F_D = 0.093(distance)^{0.311}$

Gradient Factor:
   If total gradient (gradient plus
   rolling resistance) is other than
   2%, the factor obtained from the
   following equation must be applied
   to total cost per LCY:

      $F_G = 0.907e^{[0.049(\% \ gradient)]}$

Mining operating costs - Rear-dump trucks

Used Equipment Factor:
   These factors account for added operating expenses accrued by equipment having over 10,000 h of previous
   service life. The respective equipment and labor portions of the base operating costs must be multiplied by
   factors obtained from the following equations:

      Equipment factor: $U_e = 0.984(X)^{-0.016}$

      Labor factor: $U_l = 0.943(X)^{0.021}$

Total Cost:
      Cost/LCY pay gravel = $[Y_E(U_e) + Y_L(U_l)] \times F_D \times F_G$

   The above total cost per LCY must then be multiplied by the total yearly amount of pay gravel handled by
   rear-dump truck. This product is subsequently entered in the appropriate row on table 7 for final operating
   cost calculation.

91

Scrapers

Operating Cost Equations:
These equations provide the cost of excavating and hauling pay gravel using scrapers. Costs are reported in dollars per LCY of pay gravel handled. The equations are applied to the following variable:
X = Maximum LCY of pay gravel, overburden, and tails moved hourly by scraper.

The base curves assume the following:
1. Standard scrapers.
2. 6% rolling resistance, nearly level gradient.
3. 50 min/h efficiency.
4. 1,000 ft haul distance.
5. Average operator ability.

Base Equations:

Equipment operating cost: $Y_E = 0.325(X)^{-0.210}$

Labor operating cost: $Y_L = 12.01(X)^{-0.930}$

Equipment operating costs consist of 48% fuel and lubrication, 34% tires, and 18% parts. Labor operating costs consist of 88% operator labor and 12% repair labor.
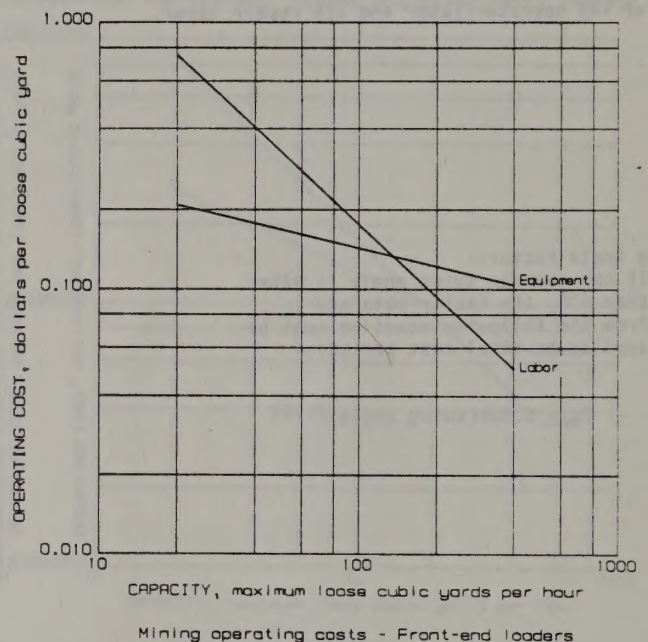
Distance Factor:
If average haul distance is other than 1,000 feet, the factor obtained from the following equation must be applied to the total cost per LCY:

$$F_D = 0.01947(\text{Distance})^{0.577}$$

Gradient Factor:
If total gradient (gradient plus rolling resistance) is other than 6%, the factor obtained from the following equation must be applied to total cost per LCY:

$$F_G = 0.776e^{[0.047(\% \text{ gradient})]}$$

Mine operating costs - Scrapers

Used Equipment Factor:
These factors account for added operating expenses accrued by equipment having over 10,000 h of previous service life. The respective equipment and labor portions of the base operating costs must be multiplied by factors obtained from the following equations:

Equipment factor: $U_e = 1.096(X)^{-0.006}$

Labor factor: $U_l = 0.845(X)^{0.034}$

Total Cost:
        Cost/LCY pay gravel = $[Y_E(U_e) + Y_L(U_l)] \times F_D \times F_G$

The above total cost per LCY must then be multiplied by the total yearly amount of <u>pay gravel</u> handled by scraper. This product is subsequently entered in the appropriate row on table 7 for final operating cost calculation.

92

Processing

Conveyors

Operating Cost Equations:
These equations provide the cost of moving gravel using conveyors. Costs are reported in dollars per cubic yard of gravel handled and include the operating cost of the conveyor along with the drive. The equations are applied to the following variable:

X = Maximum cubic yards of feed moved hourly by conveyor.

The base equations assume the following:
1. 40 ft conveyors.
2. 3,120 lb/yd^3 feed.
3. Nearly level setup.

Base Equations:

Equipment operating cost: $Y_E = 0.218(X)^{-0.561}$

Labor operating cost: $Y_L = 0.250(X)^{-0.702}$

Equipment operating costs average 72% parts, 24% electricity, and 4% lubrication. Labor operating costs consist entirely of repair labor.

Conveyor Length Factor:
If conveyor length is other than 40 ft, factors obtained from the following equations must be applied to respective portions of the operating costs:

Equipment factor:

$L_e = 0.209(length)^{0.431}$

Labor Factor:

$L_l = 0.245(length)^{0.390}$

These factors are valid for conveyors 10 to 100 ft long.
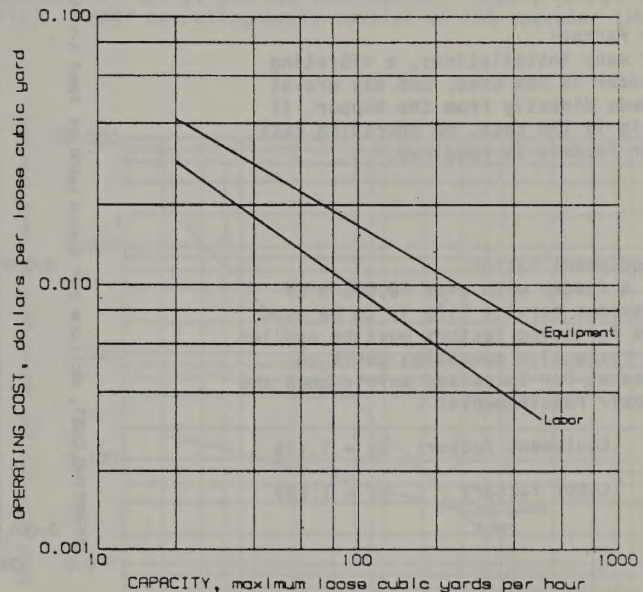
Processing operating cost - Conveyors

Used Equipment Factor:
These factors account for added operating expenses accrued by equipment having over 10,000 h of previous service life. The respective equipment and labor portions of base operating costs must be multiplied by the following factors:

Equipment factor: $U_e = 1.155$

Labor factor: $U_l = 1.250$

Total Cost:

Cost/yd^3 gravel = $[Y_E(L_e)(U_e) + Y_L(L_l)(U_l)]$

The above total cost per cubic yard must then be multiplied by the total yearly amount of <u>feed</u> handled by conveyor. (A separate operating and total yearly cost must be calculated for each conveyor in the circuit.) This product is subsequently entered in the appropriate row on table 7 for final operating cost calculation.

93

Feed Hoppers

Operating Cost Equations:
    These equations provide cost of material transfer using vibrating feeders. Costs are reported in dollars per cubic yard of feed and include the operating cost of the hopper, feeder, and drive motor. The equations are applied to the following variable:
        X = Maximum cubic yards of feed handled hourly by feed hopper.

    The base equations assume the following:
        1. Un-sized feed.
        2. 2,300 lb/yd^3 feed solids.

Base Equations:
        Equipment operating cost: $Y_E = 0.033(X)^{-0.344}$

        Labor operating cost: $Y_L = 0.017(X)^{-0.295}$

    Equipment operating costs consist of 88% parts, 6% electricity, and 6% lubrication. Labor operating costs consist entirely of repair labor.

Hopper Factor:
    In many installations, a vibrating feeder is not used, and pay gravel feeds directly from the hopper. If this is the case, no operating cost for feeders is required.

Used Equipment Factor:
    If a feeder with over 10,000 h of previous service life is to be used, the following factors must be applied to respective operating costs to account for increased maintenance and repair requirements:

        Equipment factor: $U_e = 1.176$

        Labor factor: $U_l = 1.233$

Processing operating costs - Feed hoppers
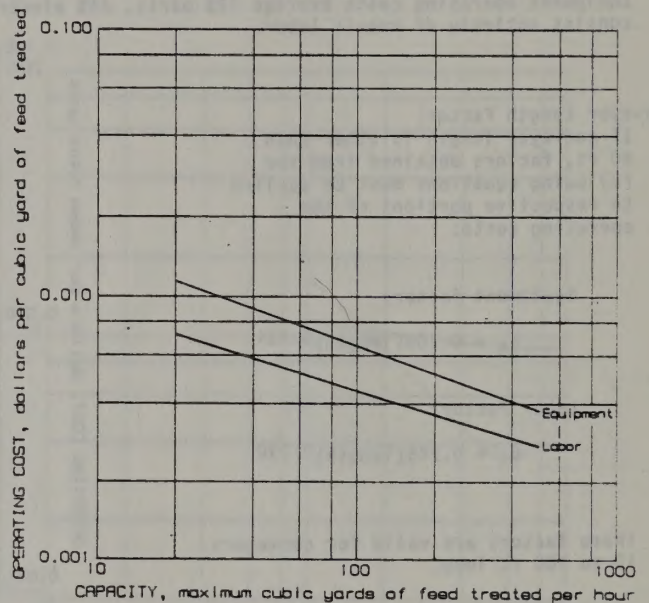
Total Cost:
        Cost/yd^3 feed = $[Y_E(U_e) + Y_L(U_l)]$

    The above total cost per cubic yard must then be multiplied by total yearly amount of feed handled by feed hopper. This product is subsequently entered in the appropriate row on table 7 for final operating cost calculation.

Operating Cost Equations:

These equations provide the cost of gravity separation using jig concentrators. Costs are reported in dollars per cubic yard of feed and include the operating cost of the jigs and associated drive motors. The equations are applied to the following variable:

X = Maximum cubic yards of feed handled hourly by jig concentrators.

The base equations assume the following:
1. Cleaner service.
2. 0.617 yd^3/ft^2 hourly capacity.
3. 3,400 lb/yd^3 feed solids.
4. 40% solids slurry density.
5. Gravity feed.

Base Equations:

Equipment operating cost: $Y_E = 0.113(X)^{-0.328}$

Supply operating cost: $Y_S = 0.002(X)^{-0.184}$

Labor operating cost: $Y_L = 3.508(X)^{-1.268}$.

Equipment operating costs consist of 40% parts, 34% electricity, and 26% lubrication. Supply operating costs consist entirely of lead shot for bedding material. Labor operating costs consist of 66% operator labor and 34% repair labor.

Rougher/Coarse Factor

If jigs are to be used for rougher service or a coarse feed, higher productivity will be realized. To compensate for this situation, the following factor must be applied to total operating cost:

Factor: $F_R = 0.344$

Used Equipment Factor:

If jig concentrators with over 10,000 h of service life are to be used, the following factors must be applied to respective operating costs to account for increased maintenance and repair requirements:

Equipment factor: $U_e = 1.096$

Labor factor: $U_l = 1.087$

Processing operating costs - Jig concentrators

Total Cost:

$$Cost/yd^3 \text{ feed} = [Y_E(U_e) + Y_S + Y_L(U_l)]^X F_R$$

The above total cost per cubic yard must then be multiplied by the total yearly amount of _feed_ handled by jig concentrators. This product is subsequently entered in the appropriate row on table 7 for final operating cost calculation.
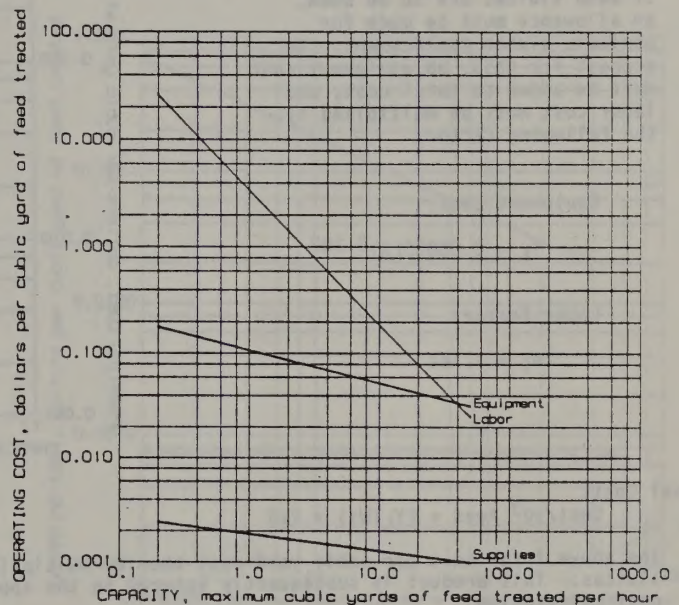
Sluices

Operating Cost Equations:
These equations provide the cost of gravity separation using sluices. Costs are reported in dollars per cubic yard of feed and consist entirely of the expense of periodic concentrate cleanup. The equation is applied to the following variable:
X = Maximum cubic yards of feed handled hourly by sluice.

The base equations assume the following:
1. Steel plate construction.
2. Angle iron riffles·
3. 3,400 lb/yd^3 feed solids.
4. 4:1 length-to-width ratio.
5. Gravity feed.

Base Equation:
Labor operating cost: $Y_L = 0.377(X)^{-0.636}$

Labor operating costs consist entirely of feed adjustment and cleanup labor. Costs of maintenance labor and parts are negligible.

Wood Sluice Factor:
If wood sluices are to be used, an allowance must be made for periodic sluice replacement. To account for this, an equipment cost must be added to total cost, and labor cost must be multiplied by the following factor:

Equipment cost:

$$Y_E = 0.00035(X)^{0.383}$$

Labor factor:

$$W_1 = 1.141$$
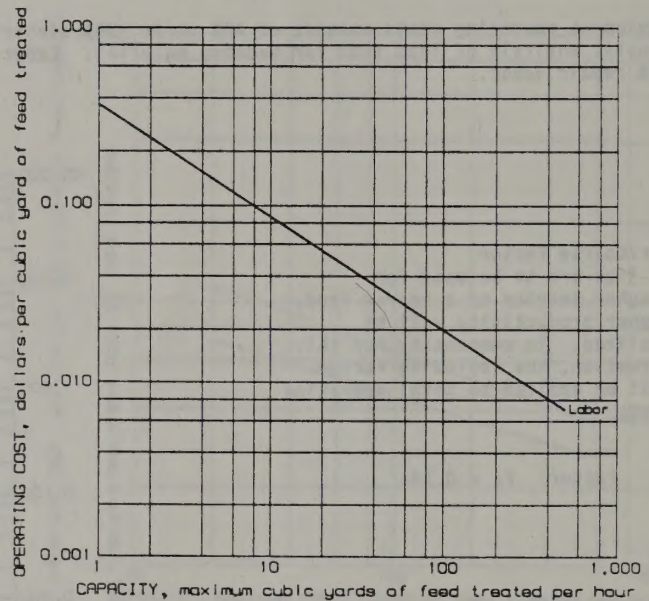
Processing operating costs - Sluices

Total Cost:
Cost/yd^3 feed = $[Y_L(W_1) + Y_E]$

The above total cost per cubic yard must then be multiplied by total yearly amount of _feed_ handled by sluices. This product is subsequently entered in the appropriate row on table 7 for final operating cost calculation.

96

Spiral Concentrators

Operating Cost Equations:
These equations provide the cost of gravity separation using spiral concentrators. Costs are reported in dollars per cubic yard of feed and include the operating cost of the spirals and slurry splitters only. The equations are applied to the following variable:

X = Maximum cubic yards of feed handled hourly by spiral concentrators.

The base equations assume the following:
1. Rougher service.
2. 1.75 ton/h solids per start.
3. 3,400 lb/yd^3 feed solids.
4. 10% solids slurry density.
5.. Gravity feed.

Base Equations:

Equipment operating cost: $Y_E = \$ 0.0007/yd^3$

Labor operating cost: $Y_L = 0.755(X)^{-0.614}$

Equipment operating costs consist entirely of parts. Labor operating costs consist entirely of operator labor, with the operator performing functions such as lining replacement.

Cleaner/Scavenger Factor:
If spirals are to be used for cleaning or scavenging, throughput is reduced. The following factors must be applied to respective operating costs:

Equipment factor: $C_e = 2.429$

Labor factor: $C_l = 1.796$

Used Equipment Factor:
Since spiral concentrators have no moving parts, they enjoy a long service life. Generally, only the liners require periodic replacement. For this reason, the operating costs associated with spirals are typically constant throughout the life of the machine.
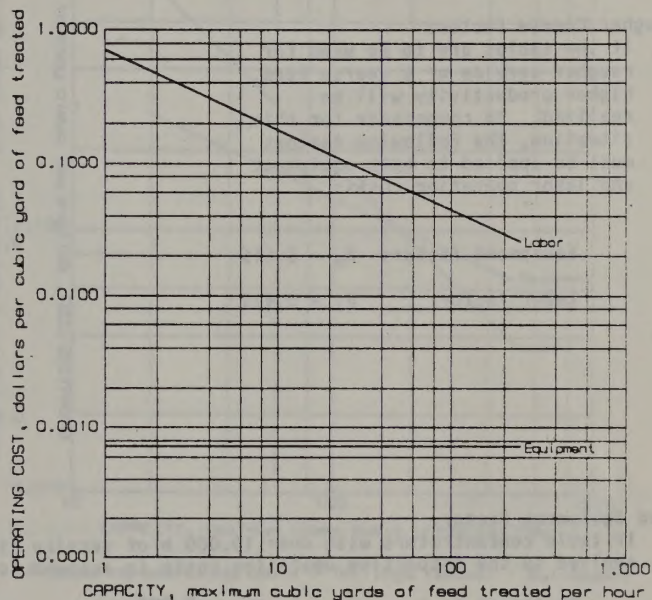
Processing operating costs - Spiral concentrators

Total Cost:
$$Cost/yd^3 \text{ feed} = [0.0007(C_e) + Y_L(C_l)]$$

The above total cost per cubic yard must then be multiplied by the total yearly amount of _feed_ handled by spiral concentrators. This product is subsequently entered in the appropriate row on table 7 for final operating cost calculation.

97

Table Concentrators

Operating Cost Equations:
These equations provide the cost of gravity separation using table concentrators. Costs are reported in dollars per cubic yard of feed and include the operating cost of the tables and associated drive motors. The equations are applied to the following variable:
   X = Maximum cubic yards of feed handled hourly by table concentrators.

The base equations assume the following:
   1. Cleaner service.
   2. 3,400 lb/yd^3 feed solids.
   3. 25% solids slurry density.
   4. Gravity feed.

Base Equations:
   Equipment operating cost: $Y_E = 1.326(X)^{-0.443}$

   Labor operating cost: $Y_L = 1.399(X)^{-0.783}$

Equipment operating costs consist of 88% parts, 7% electricity, and 6% lubrication. Labor operating costs consist of 67% operator labor and 33% repair labor.

Rougher/Coarse Factor:
If the tables are to be used for rougher service or a coarse feed, higher productivity will be realized. To compensate for this situation, the following factors must be applied to both equipment and labor operating costs:

   Equipment factor: $R_e = 0.415$

   Labor factor: $R_1 = 0.415$
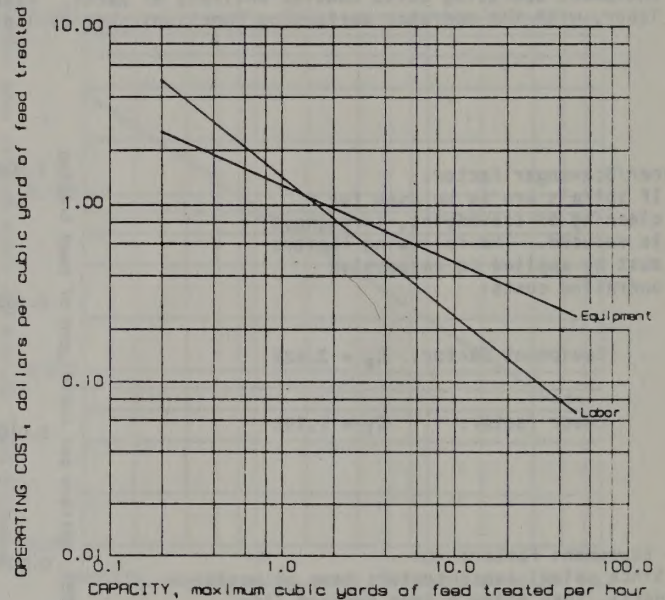
Processing operating costs - Table concentrators

Used Equipment Factor:
If table concentrators with over 10,000 h of service life are to be used, the following factors must be applied to the respective operating costs to account for increased maintenance and repair requirements:

   Equipment factor: $U_e = 1.217(X)^{-0.002}$

   Labor factor: $U_1 = 1.121(X)^{-0.026}$

Total Cost:

   Cost/yd^3 feed = $[Y_E(R_e)(U_e) + Y_L(R_1)(U_1)]$

The above total cost per cubic yard must then be multiplied by the total yearly amount of <u>feed</u> handled by table concentrators. This product is subsequently entered in the appropriate row on table 7 for final operating cost calculation.

Bulldozers

Operating Cost Equations:
These equations provide the cost of removing and relocating tailings using bulldozers. Costs are reported in dollars per cubic yard of tailings moved. The equations are applied to the following variable:
X = Maximum LCY of pay gravel, overburden, and tails moved hourly by bulldozer.

The base equations assume the following:
1. 50 min/h efficiency.
2. 300 ft dozing distance.
3. Average operator ability.
4. Nearly level gradient.

Base Equations:

Equipment operating cost: $Y_E = 0.993(X)^{-0.430}$

Labor operating cost: $Y_L = 14.01(X)^{-0.945}$

Equipment operating costs average 47% parts, and 53% fuel and lubrication. Labor operating costs average 86% operator labor and 14% repair labor.

Distance Factor:
If average dozing distance is other than 300 ft, the factor obtained from the following equation must be applied to total cost per LCY:

$F_D = 0.00581(distance)^{0.904}$

Gradient Factor:
If average gradient is other than level, the factor obtained from the following equation must be applied to total cost per LCY:

$F_G = 1.041e^{[0.015(\% \text{ gradient})]}$

Processing operating costs - Tailings removal - Bulldozers

Used Equipment Factor:
These factors account for added operating expenses accrued by equipment having over 10,000 h of previous service life. The respective equipment and labor portions of the base operating costs must be multiplied by factors obtained from the following equations:

Equipment factor: $U_e = 1.206(X)^{-0.013}$

Labor factor: $U_1 = 0.967(X)^{0.015}$

Total Cost:

Cost/LCY tailings = $[Y_E(U_e) + Y_L(U_1)] \times F_D \times F_G$

The above total cost per cubic yard must then be multiplied by the total yearly amount of tailings moved by bulldozer. This product is subsequently entered in the appropriate row on table 7 for final operating cost calculation.

99

Operating Cost Equations:
These equations provide the cost of removing and relocating tailings using draglines. Costs are reported in dollars per cubic yard of tailings moved. The equations are applied to the following variable:
X = Maximum LCY of pay gravel, overburden, and tails moved hourly by dragline.

The base curves assume the following:
1. 0.90 bucket efficiency.
2. Full hoist.
3. $90°$ swing angle.
4. Average operator ability.

Base Equations:

Equipment operating cost: $\qquad Y_E = 1.984(X)^{-0.390}$

Labor operating cost: $\qquad Y_L = 12.19(X)^{-0.888}$

Equipment operating costs consist of 67% parts 33% fuel and lubrication. Labor operating costs consist of 78% operator labor and 22% repair labor.

Swing Angle Factor:
If the average swing angle is other than $90°$, the factor obtained from the following equation must be applied to total cost per LCY:

$$F_S = 0.304(\text{swing angle})^{0.269}$$

Processing operating costs - Tailings removal - Draglines

Used Equipment Factor:
These factors account for added operating expenses accrued by equipment having over 10,000 h of previous service life. The respective equipment and labor portions of the base operating costs must be multiplied by factors obtained from the following equations:

Equipment factor: $\qquad U_e = 1.162(X)^{-0.017}$

Labor factor: $\qquad U_1 = 0.989(X)^{0.006}$

Total Cost:
Cost/LCY tailings = $[Y_E(U_e) + Y_L(U_1)] \times F_S$

The above total cost per cubic yard must then be multiplied by the total yearly amount of <u>tailings</u> moved by dragline. This product is subsequently entered in the appropriate row on table 7 for final operating cost calculation.

Front-End Loaders

Operating Cost Equations:

These equations provide the cost of removing and relocating tailings using wheel front-end loaders. Costs are reported in dollars per cubic yard of tailings moved. The equations are applied to the following variable:

X = Maximum LCY of pay gravel, overburden, and tails moved hourly by front-end loader.

The base equations assume the following:
1. 500 ft haul distance.
2. 2% rolling resistance, nearly level gradient.
3. Inconsistent operation.
4. Wheel-type loader.

Base Equations:

Equipment operating cost: $\quad Y_E = 0.407(X)^{-0.225}$

Labor operating cost: $\quad Y_L = 13.07(X)^{-0.936}$

Equipment operating costs average 22% parts, 46% fuel and lubrication, and 32% tires. Labor operating costs average 90% operator labor and 10% repair labor.

Distance Factor:

If average haul distance is other than 500 ft, the factor obtained from the following equation must be applied to total cost per LCY:

$$F_D = 0.023(Distance)^{0.616}$$

Gradient Factor:

If total gradient (gradient plus rolling resistance) is other than 2%, the factor obtained from the following equation must be applied to total cost per LCY:

$$F_G = 0.877e^{[0.046(\% \text{ gradient})]}$$

Processing operating costs - tailings removal - Front-end loaders

Used Equipment Factor:

These factors account for added operating expenses accrued by equipment having over 10,000 h of previous service life. The respective equipment and labor portions of base operating costs must be multiplied by factors obtained from the following equations:

Equipment factor: $\quad U_e = 1.162(X)^{-0.017}$

Labor factor: $\quad U_1 = 0.989(X)^{0.006}$

Track-Type Loader Factor:

If track-type loaders are used, the following factors must be applied to total cost obtained from the base equations:

Equipment factor: $\quad T_e = 1.378$

Labor factor: $\quad T_1 = 1.073$

Total Cost:

Cost/LCY tailings = $[Y_E(U_e)(T_e) + Y_L(U_1)(T_1)] \times F_D \times F_G$

The above total cost per cubic yard must then be multiplied by the total yearly amount of <u>tailings</u> moved by front-end loader. This product is subsequently entered in the appropriate row on table 7 for final operating cost calculation.

Rear-Dump Trucks

Operating Cost Equations:
These equations provide the cost of relocating tailings using rear-dump trucks. Costs are reported in dollars per cubic yard of tailings moved. The equations are applied to the following variable:

X = Maximum LCY of pay gravel, overburden, and tails moved hourly by rear-dump truck.

The base equations assume the following:
1. 2,500 ft haul distance.
2. 4 loader cycles to fill.
3. 50 min/h efficiency.
4. Average operator ability.
5. 2% rolling resistance, nearly level gradient.

Base Equations:

Equipment operating cost: $Y_E = 0.602(X)^{-0.296}$

Labor operating cost: $Y_L = 11.34(X)^{-0.891}$

Equipment operating costs consist of 28% parts, 58% fuel and lubrication, and 14% tires. Labor operating costs consist of 82% operator labor and 18% repair labor.
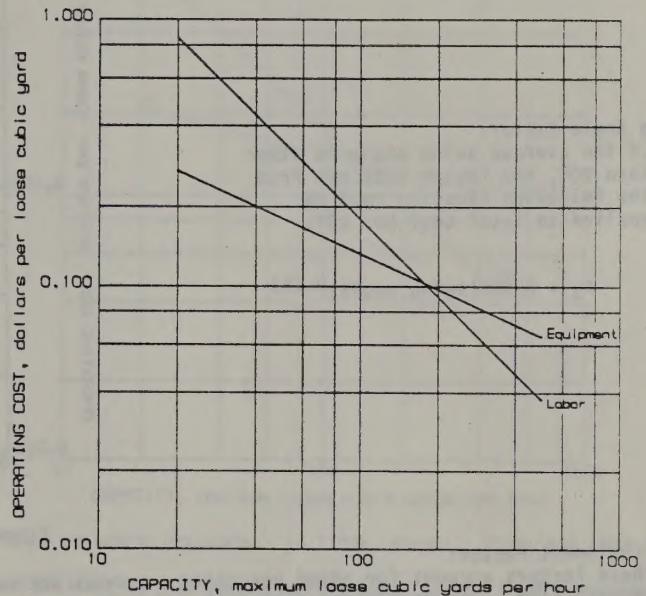
Distance Factor:
If average haul distance is other than 2,500 ft, the factor obtained from the following equation must be applied to total cost per LCY:

$$F_D = 0.093(distance)^{0.311}$$

Gradient Factor:
If total gradient (gradient plus rolling resistance) is other than 2%, the factor obtained from the following equation must be applied to total cost per LCY:

$$F_G = 0.907e^{[0.049(\% \ gradient)]}$$

Processing operating costs - Tailings removal - Rear-dump trucks

Used Equipment Factor:
These factors account for added operating expenses accrued by equipment having over 10,000 h of previous service life. The respective equipment and labor portions of base operating costs must be multiplied by factors obtained from the following equations:

Equipment factor: $U_e = 0.984(X)^{0.016}$

Labor factor: $U_l = 0.943(X)^{0.021}$

Total Cost:
Cost/LCY tailings = $[Y_E(U_e) + Y_L(U_l)] \times F_D \times F_G$

The above total cost per cubic yard must then be multiplied by the total yearly amount of <u>tailings</u> moved by truck. This product is subsequently entered in the appropriate row on table 7 for final operating cost calculation.

Scrapers

Operating Cost Equations:
These equations provide the cost of removing and relocating tailings using scrapers. Costs are reported in dollars per cubic yard of tailings moved. The equations are applied to the following variable:

X = Maximum LCY of pay gravel, overburden, and tails moved hourly by scraper.

The base curves assume the following:
1. Standard scrapers.
2. 6% rolling resistance, nearly level gradient.
3. 50 min/h efficiency.
4. 1,000 ft haul distance.
5. Average operator ability.

Base Equations:

Equipment operating cost: $Y_E = 0.325(X)^{-0.210}$

Labor operating cost: $Y_L = 12.01(X)^{-0.930}$

Equipment operating costs consist of 48% fuel and lubrication, 34% tires, and 18% parts. Labor operating costs consist of 88% operator labor and 12% repair labor.

Distance Factor:
If average haul distance is other than 1,000 ft, the factor obtained from the following equation must be applied to total cost per LCY:

$$F_D = 0.01947(Distance)^{0.577}$$

Gradient Factor:
If total gradient (gradient plus rolling resistance) is other than 6%, the factor obtained from the following equation must be applied to total cost per LCY:

$$F_G = 0.776e^{[0.047(\% \text{ gradient})]}$$

Processing operating costs - Tailings removal - Scrapers

Used Equipment Factor:
These factors account for added operating expenses accrued by equipment having over 10,000 h of previous service life. The respective equipment and labor portions of base operating costs must be multiplied by factors obtained from the following equations:

Equipment factor: $U_e = 1.096(X)^{-0.006}$

Labor factor: $U_l = 0.845(X)^{0.034}$

Total Cost:
Cost/LCY tailings = $[Y_E(U_e) + Y_L(U_l)] \times F_D \times F_G$

The above total cost per cubic yard must then be multiplied by total yearly amount of _tailings_ moved by scraper. This product is subsequently entered in the appropriate row on table 7 for final operating cost calculation.

Operating Cost Equations:
These equations provide the cost of processing gravel using trommels. Costs are reported in dollars per cubic yard of gravel handled. The equations are applied to the following variable:
X = Maximum cubic yards of gravel processed hourly by trommels.

The base equations assume the following:
1. Trommels are sectioned for scrubbing and sizing.
2. Associated electric motor operating costs are included.

Base Equations:

Equipment operating cost: $Y_E = 0.217(X)^{-0.403}$

Labor operating cost: $Y_L = 0.129(X)^{-0.429}$

Equipment operating costs average 63% parts, 26% electricity, and 11% lubrication. Labor operating costs consist entirely of maintenance and repair labor.

Used Equipment Factor:
These factors account for added operating expenses accrued by equipment having over 10,000 h of previous service life. The respective equipment and labor portions of base operating costs must be multiplied by the following factors:

Equipment factor: $U_e = 1.194$

Labor factor: $U_l = 1.310$
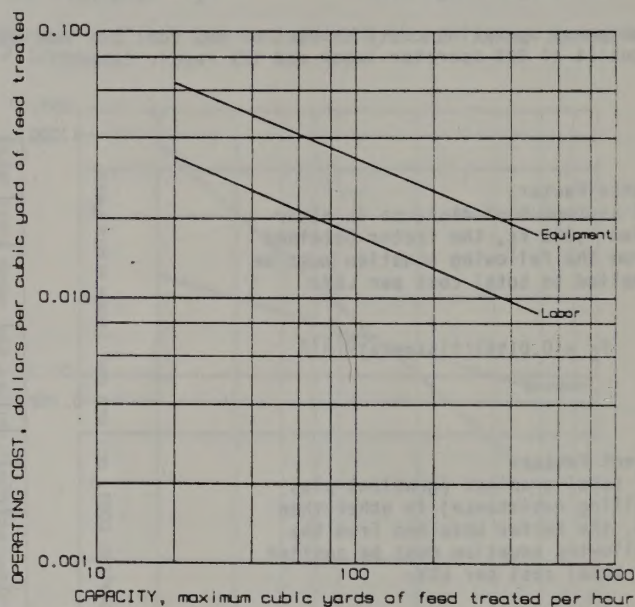
Processing operating costs - Trommels

Total Cost:
Cost/yd^3 gravel = $[Y_E(U_e) + Y_L(U_l)]$

The above total cost per cubic yard must then be multiplied by the total yearly amount of gravel processed by trommels. This product is subsequently entered in the appropriate row on table 7 for final operating cost calculation.

Vibrating Screens

Operating Cost Equations:

These equations provide the cost of processing gravel using vibrating screens. Costs are reported in dollars per cubic yard of gravel handled. The equations are applied to the following variable:

X = Maximum cubic yards of gravel processed hourly by vibrating screen.

The base equations assume the following:
1. An average of 0.642 ft^2 of screen is required for every cubic yard of hourly capacity.
2. Associated electric motor operating costs are included.
3. 3,120 lb/yd^3 feed solids.
4. Gravity feed.

Base Equations:

Equipment operating cost: $\qquad Y_E = 0.104(X)^{-0.426}$

Labor operating cost: $\qquad Y_L = 0.106(X)^{-0.570}$

Equipment operating costs average 73% parts, 19% electricity, and 8% lubrication. Labor operating costs consist entirely of maintenance and repair labor.

Capacity Factor:

If anticipated screen capacity is other than 0.624 ft^2/yd^3 hourly feed capacity, the respective operating costs must be multiplied by factors obtained from the following equations:

$$C_e = 1.267(C)^{0.575}$$

$$C_l = 1.207(C)^{0.458}$$

where C = anticipated capacity in square feet of screen per cubic yard of hourly feed.
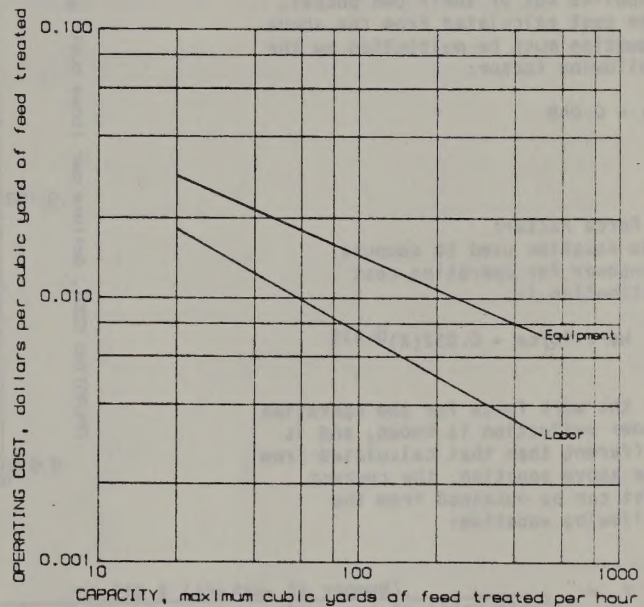
Processing operating costs - Vibrating screens

Used Equipment Factor:

These factors account for added operating expenses accrued by equipment having over 10,000 h of previous service life. The respective equipment and labor portions of base operating costs must be multiplied by the following factors:

Equipment factor: $\quad U_e = 1.197$

Labor factor: $\qquad U_l = 1.131$

Total Cost:

Cost/yd^3 gravel = $[Y_E(C_e)(U_e) + Y_L(C_l)(U_l)]$

The above total cost per cubic yard must then be multiplied by the total yearly amount of gravel processed by the vibrating screen. This product is subsequently entered in the appropriate row on table 7 for final operating cost calculation.

Supplemental

Employee Housing

Operating Cost Equation:
This equation furnishes the operating cost associated with providing housing for workers at the minesite. Costs are reported in dollars per cubic yard of overburden and pay gravel. Expenses for food, supplies, water, heat, and electricity are all taken into account. The equation is applied to the following variable:
X = Average cubic yards of overburden and pay gravel handled hourly.

The base equation assumes the following:
1. 10 h/shift.

Base Equation:
Supply operating cost: $Y_S = 1.445(X)^{-0.583}$

Supply operating costs average 95% industrial materials and 5% fuel.

Food Allowance Factor:
If workers are to pay for food and supplies out of their own pocket, the cost calculated from the above equation must be multiplied by the following factor:

$F_F = 0.048$

Work Force Factor:
The equation used to compute manpower for operating cost estimation is:

Work force = $0.822(X)^{0.415}$

If the work force for the operation under evaluation is known, and is different than that calculated from the above equation, the correct cost can be obtained from the following equation:

$$Y_S = \frac{(\text{Number of workers}) \times \$17.85}{\text{Cubic yards of overburden and pay gravel handled daily}}$$

Supplemental operating costs - Employee housing

Total Cost:
Cost/LCY = $Y_S \times F_F$

The above total cost per LCY must then be multiplied by the total yearly amount of <u>overburden</u> and <u>pay gravel</u> handled. This product is subsequently entered in the appropriate row on table 7 for final operating cost calculation.
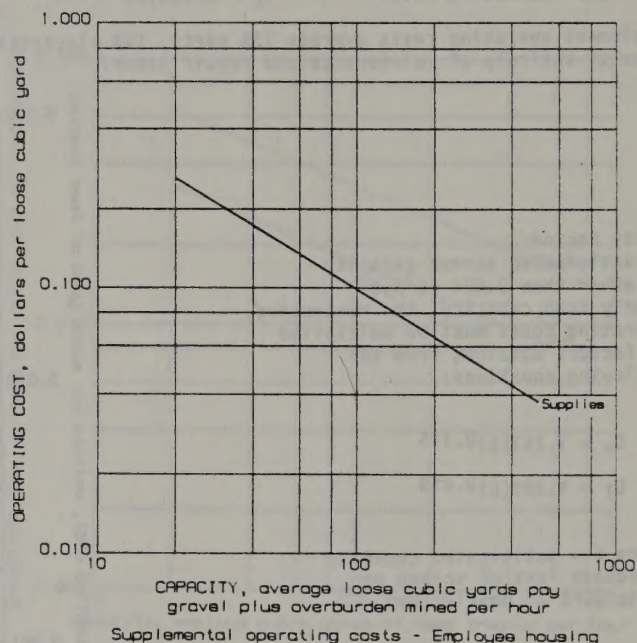
Generators

Operating Cost:

Operating costs of diesel generators are accounted for in the electrical portions of the other equipment operating costs. By so doing, operating costs of the generators are tied directly to size and type of equipment used.

The electrical portions of operating cost curves will also account for the expense of electricity brought in through transmission lines if diesel generators are not used. This is at best an approximation. However, costs assigned in this manner are typically more representative than costs calculated by trying to estimate the total power consumption of an operation.

Operating Cost Equations:

These equations account for costs not directly related to production. Costs are reported in dollars per cubic yard. Items in this section include:

1. Equipment downtime.
   a. Productivity lost by the entire crew due to breakdown of key pieces of equipment.
   b. Productivity lost by individual operators due to breakdown of single pieces of equipment.
   c. Labor charges of outside maintenance personnel.
   d. Wash plant relocation.

2. Site maintenance.
   a. Road maintenance.
   b. Stream diversion.
   c. Drainage ditch construction and maintenance.
   d. Site cleanup.
   e. Reclamation grading and recontouring.
   f. Settling pond maintenance.

3. Concentrate refinement.
   a. Time spent recovering valuable minerals from mill concentrates by panning, mechanical separation, or amalgamation.

The equations are applied to the following variable:
X = Maximum cubic yards of feed handled hourly by mill.

Base Equations:

Equipment operating cost: $Y_E = 0.142(X)^{0.004}$

Labor operating cost: $Y_L = 2.673(X)^{-0.524}$

Equipment operating costs average 53% fuel and lubrication, and 47% equipment parts. Labor operating costs consist of 91% operator labor and 9% maintenance and repair labor.

Total Cost:

$$Cost/yd^3 = Y_E + Y_L$$

The above total cost per cubic yard must then be multiplied by the total yearly amount of overburden, pay gravel, and tailings handled. This product is subsequently entered in the appropriate row on table 7 for final operating cost calculation.
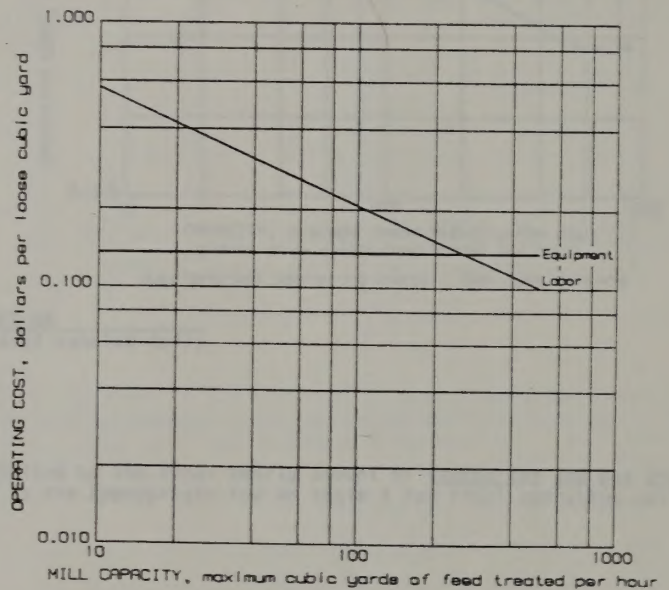
Supplemental operating costs - Lost time and general services

Pumps

Operating Cost Equations:
These equations provide the cost of transporting and providing water using centrifugal pumps. Costs are reported in dollars per hour of pump use. If more than one pump is used in the operation, a separate cost must be calculated for each. The equations are applied to the following variable:
X = Maximum gallons of water required per minute.

The base equations assume the following:
1. Total head of 25 ft.
2. Diesel powered pumps.
3. Abrasion-resistant steel construction.
4. Total engine-pump efficiency of 60%.

Base Equations:
Equipment operating cost: $Y_E = 0.007(X)^{0.713}$

Labor operating cost: $Y_L = 0.004(X)^{0.867}$

Equipment operating costs average 59% fuel and lubrication, and 41% parts. Labor operating costs consist of 82% operator labor, and 18% maintenance and repair labor. (Operator labor includes pipeline work.)

Head Factor:
If total pumping head is other than 25 ft, factors calculated from the following equations will correct for changes in equipment and labor operating costs. The product of these factors and the original costs will provide the appropriate figures:

$H_e = 0.091(H)^{0.735}$

$H_1 = 0.054(H)^{0.893}$

where H = total pumping head.
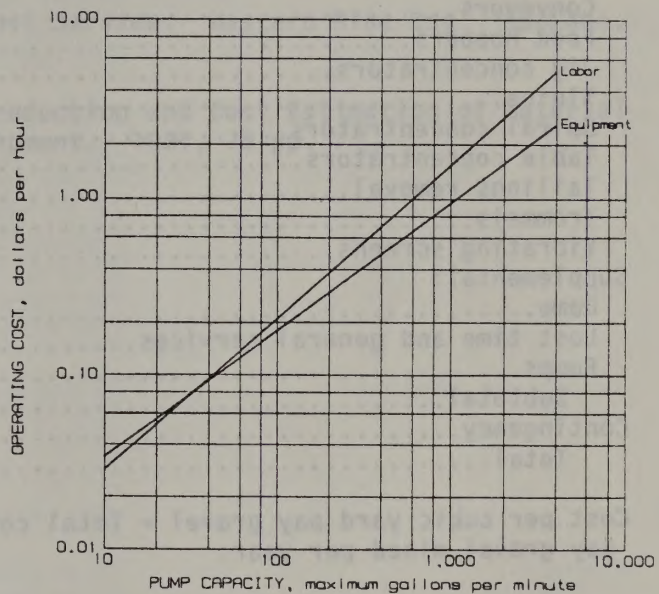
Supplemental operating costs - Pumps

Used Equipment Factor:
These factors account for added operating expenses accrued by equipment having over 10,000 h of previous service life. The respective equipment and labor portions of base operating costs must be multiplied by the following factors:

Equipment factor: $U_e = 1.096$

Labor factor: $U_1 = 1.067$

Total Cost:
Cost/h = $[Y_E(H_e)(U_e)] + [Y_L(H_1)(U_1)]$

The above total cost per hour must then be multiplied by the anticipated hours per year of pump use. This product is subsequently entered in the appropriate row on table 7 for final operating cost calculation.

TABLE 7. - Operating cost summary form

Item	Cost/a
Overburden Removal:	
Bulldozers...	$
Draglines...	
Front-end loaders..................................	
Rear-dump trucks..................................	
Scrapers...	
Mining:	
Backhoes...	
Bulldozers...	
Draglines...	
Front-end loaders..................................	
Rear-dump trucks..................................	
Scrapers...	
Processing:	
Conveyors...	
Feed hoppers...	
Jig concentrators..................................	
Sluice..	
Spiral concentrators..............................	
Table concentrators..............................	
Tailings removal..................................	
Trommels...	
Vibrating screens..................................	
Supplemental:	
Camp..	
Lost time and general services..................	
Pumps..	
Subtotal...	
Contingency...	
Total..	

Cost per cubic yard pay gravel = Total cost per cubic yard
 pay gravel mined per year.

 Final cost per cubic yard pay gravel....................

110

BIBLIOGRAPHY

Caterpillar Tractor Co. Peoria, IL. Caterpillar Performance Handbook. 15th ed., 1984, 600 pp.

Dataquest Inc. Cost Reference Guide for Construction Equipment. Equipment Guide Book Co., Palo Alto, CA. Periodically updated.

Godfrey, R. S. Means Building Construction Cost Data, 1985. Robert Snow Means Co., Inc., Kingston, MA. 43d ed., 1984, 455 pp.

Marshall and Swift. Los Angeles, CA. Marshall Valuation Service. Periodically updated.

Richardson Engineering Services, Inc. San Marcos, CA. Process Plant Construction Estimating Standards. Periodically updated.

Schumacher, O. L. Mining Cost Service. Western Mine Eng. Spokane, WA. Periodically updated.

Terex Corp. Hudson, OH. Production and Cost Estimating of Material Movement with Earthmoving Equipment. 1981, 78 pp.

APPENDIX.--EXAMPLE OF COST ESTIMATE

SAMPLE ESTIMATION

PARAMETERS

General:

150 operating d/a.
10 h/shift.
100 LCY/h pay gravel capacity.
2.5 LCY stripping ratio.
150,000 LCY/a pay gravel mined.
375,000 LCY/a overburden removed.
Workers live on-site.

Exploration:

20 worker-days reconnaissance.
1,400 ft churn drilling.
2,000 yd^3 trenching.
1,200 samples panned.
8 h helicopter time.
180 worker-days camp requirements.

Development:

4 mi access road.
20% sideslope.
Forested.
22 ft wide.
Ungraveled.
6 acres cleared.
Forested.
10% sideslope.

Overburden removal:

Excavated and hauled by one scraper.
250 LCY/h production capacity.
30,000 LCY prior to production.
3,000 ft average haul distance.
+8% average haul gradient.

Mining:

Excavated by one backhoe.
Hauled by two front-end loaders.
100 LCY/h production capacity.
Medium-hard digging.
800 ft average haul length.
+6% average haul gradient.

Mine equipment:

1 new backhoe.
1 used bulldozer.
2 new front-end loaders.
1 used scraper.

112

<u>Milling:</u>   Jig plant (see accompanying flow sheet).
                              Feeder: 100 LCY/h.
                              Trommel: 100 LCY/h.
                              Rougher jig: 20 yd^3/h.
                              Cleaner jigs: 2 @ 5 yd^3/h.
                              Final jig: 0.2 yd^3/h.
                              Scavenger sluice: 50 yd^3/h.
                              Scavenger sluice: 20 yd^3/h.
                              Conveyor: 70 yd^3/h, 40 ft.

<u>Tailings placement:</u>   Transported using 1 bulldozer.
                              100 LCY/h production capacity.
                              400 ft average haul length.
                              Minus 8% average gradient.

ESCALATION FACTORS:

Labor	–	11.98/11.69	= 1.025
Equipment	–	362.3/360.4	= 1.005
Steel	–	354.6/357.4	= 0.992
Lumber	–	354.9/343.2	= 1.034
Fuel	–	630.7/636.2	= 0.991
Tires	–	246.0/262.0	= 0.939
Construction materials	–	363.63/358.32	= 1.015
Electricity	–	540.3/524.9	= 1.029
Industrial materials	–	324.3/323.2	= 1.003

113
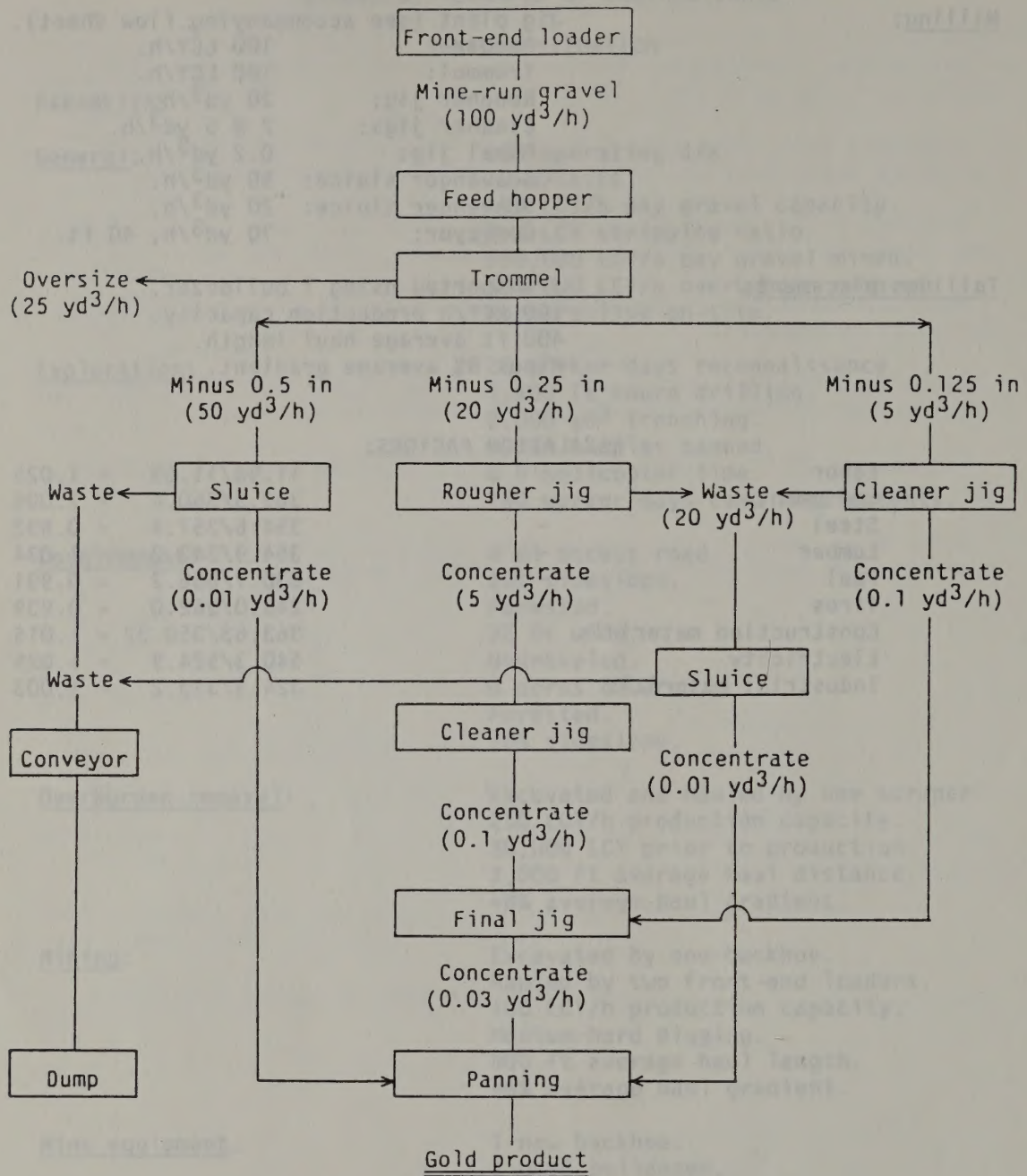
FIGURE A-1. - Sample flow sheet.

114

Capital Costs

Exploration (p.____):

Reconnaissance	= 20 worker-days X $195.00/worker-day	=	$3,900
Churn drilling	= 1,400 ft X $45/ft	=	$63,000
Trenching	= 2,000 yd^3 X $7.10/yd^3	=	$14,200
Panning	= 1,200 samples X $2.10/sample	=	$2,520
Helicopter	= 8 hours X $395/h	=	$3,160
Camp	= 180 worker-days X $30/worker-day	=	$5,400

Exploration capital cost = $92,180 x 1.25 (labor)   = $94,485

Access Roads (p.____):
    22 ft wide
    4 mi long
    20% sideslope
    forested
    600 ft blasting

Base cost: $Y_C = 765.65(22)^{0.922} = \$13,236/mi$

Labor	= $13,236 X 0.68 X 1.025	=	$9,225	
Parts	= $13,236 X 0.13 X 1.005	=	$1,729	
Fuel	= $13,236 X 0.16 X 0.991	=	$2,099	
Tires	= $13,236 X 0.03 X 0.939	=	$373	
			$13,426/mi	

Forest factor; $F_F = 2.000(22)^{-0.079} =$ 1.567
Side slope factor; $F_S = 0.633e^{[0.021(20)]} =$ 0.936
Blasting factor; $F_B = [12,059.18(22)^{0.534}] \times (600/5280) = 7,140.000$

Access Road Capital Cost =
[($13,426 X 1.567 X .963) X 4] + 7,140 = $88,180

Clearing (p.____):
    6 acres
    10% sideslope
    forested

Base cost: $Y_C = 1,043.61(6)^{0.913} = \$5,358$

Labor	= $5,358 X 0.68 X 1.025 =	$3,735	
Parts	= $5,358 X 0.12 X 0.991 =	$637	
Fuel	= $5,358 X 0.18 X 1.006 =	$970	
Steel	= $5,358 X 0.02 X 0.992 =	$106	
		$5,448	

Slope factor: $F_S = 0.942e^{[0.008(10)]} = 1.020$
Forest factor: $F_F =$ 1.750

Clearing Capital Cost =
[$5,448 X 1.020 X 1.750] = $9,725

Capital Costs

Pre-production overburden removal (p.   ):
    30,000 LCY
    250 LCY/h
    3,000 ft haul
    +8% haul gradient plus rolling resistance
    With used scraper

Equipment cost:
$$Y_E = 0.325(250)^{-0.210} = \$0.102/LCY$$

    Parts   = \$0.102 X 0.18 X 1.005 = \$0.018
    Fuel and lube   = \$0.102 X 0.48 X 0.991 = \$0.049
    Tire   = \$0.102 X 0.34 X 0.939 = $\underline{\$0.033}$
                                                  \$0.100/LCY

Labor cost:
$$Y_L = 12.01(250)^{-0.930} = \$0.071/LCY$$

    Labor   = \$0.071 X 1.00 X 1.025 = \$0.073/LCY

Distance factor: $F_D = 0.01947(3,000)^{0.577} = 1.975$
Gradient factor: $F_G = 0.776e^{[0.047(8)]} = 1.130$
Used equipment: $U_E = 1.096(250)^{-0.006} = 1.060$
                       $U_L = 0.845(250)^{0.034} = 1.019$

Overburden Removal Capital Cost =
    [(\$0.100 X 1.060) + (\$0.073 X 1.019)] X 1.975 X 1.130 X 30,000 = $\underline{\$12,077}$

Mine equipment - backhoes (p.   ):
    100 LCY/h
    80% maximum digging depth
    Medium-hard digging

Base cost:
$$Y_C = 84,132.01e^{[0.00350(100)]} = \$119,389$$

    Equipment   = \$119,389 X 1.00 X 1.005 = \$119,986

Digging depth factor: $F_D = 0.04484(80)^{0.790} = $ 1.429
Digging difficulty factor: $F_H = $ 1.556

Backhoe Capital Cost =
    (\$119,986 X 1.429 X 1.556) = $\underline{\$266,792}$

Capital Costs

Mine equipment – bulldozers (p.   ):
    100 LCY/h
    400 ft average haul distance
    Minus 8% average haul gradient
    Used equipment

Base cost: $Y_C = 3,555.96(100)^{0.806} = \$145,531$

    Equipment $= \$145,531.00 \times 1.00 \times 1.005 = \$146,259$

Distance factor: $F_D = 0.01549(400)^{0.732} \quad = \quad 1.244$
Gradient factor: $F_G = 1.041e^{[0.015(-8)]} \quad = \quad 0.923$
Used equipment factor: $F_U = \quad\quad\quad\quad\quad\quad\quad\quad 0.411$

Bulldozer Capital Cost =
    $(\$146,259 \times 1.244 \times 0.923 \times 0.411) =$ $\underline{\$69,022}$

Mine equipment – front-end loaders (p.   ):
    100 LCY/h
    Two 50-yd^3 machines
    800 ft average haul
    +6% haul gradient plus rolling resistance

Base cost: $Y_C = 2,711.10(50)^{0.896} = \$90,245$

    Equipment $= \$90,245 \times 1.00 \times 1.005 = \$90,696$

Distance factor: $F_D = 0.033(800)^{0.552} \quad = \quad 1.321$
Gradient factor: $F_G = 0.888e^{[0.041(6)]} \quad = \quad 1.136$

Front-end Loader Capital Cost =
    $(2 \times \$90,696 \times 1.321 \times 1.136) =$ $\underline{\$272,207}$

Mine equipment – scrapers (pg.   ):
    250 LCY/h
    3,000-ft average haul
    +8% haul gradient plus rolling resistance
    Used equipment

Base cost: $Y_C = 1,744.42(250)^{0.934} = \$302,919$

    Equipment $= \$302,919 \times 1.00 \times 1.005 = \$304,434$

Distance factor: $F_D = 0.025(3,000)^{0.539} \quad = \quad 1.871$
Gradient factor: $F_G = 0.776e^{[0.047(8)]} \quad = \quad 1.130$
Used equipment factor: $F_U = \quad\quad\quad\quad\quad\quad\quad\quad 0.312$

Scraper Capital Cost =
    $(\$304,434 \times 1.871 \times 1.130 \times 0.312) =$ $\underline{\$200,817}$

Processing equipment - conveyors (p.____):
   70 yd^3/h
   40 ft long

   Base cost: $Y_C = 4,728.36(70)^{0.287} = \$16,005$

       Equipment price   = $16,005 X 0.89 X 1.005 = $14,316
       Installation labor   = $16,005 X 0.08 X 1.025 = $1,312
       Construction materials = $16,005 X 0.03 X 1.015 = $487

Conveyor Capital Cost =
   ($14,316 + $1,312 + $487) = $16,115

Processing equipment - feed hopper (p.____):
   100 LCY/h

   Base cost: $Y_C = 458.48(100)^{0.470} = \$3,993$

       Equipment price   = $3,993 X 0.82 X 1.005 = $3,291
       Installation labor   = $3,993 X 0.14 X 1.025 = $573
       Steel   = $3,993 X 0.04 X 0.992 = $158

Feed Hopper Capital Cost =
   ($3,291 + $573 + $158) = $4,022

Processing equipment - rougher jig (p.____):
   20 yd^3/h

   Base cost: $Y_C = 6,403.82(20)^{0.595} = \$38,067$

       Equipment price   = $38,067 X 0.62 X 1.005 = $23,720
       Installation labor   = $38,067 X 0.24 X 1.025 = $9,364
       Construction materials = $38,067 X 0.14 X 1.015 = $5,409

   Rougher factor: $F_R = 0.531$

Rougher Jig Capital Cost =
   [($23,720 + $9,364 + $5,409) X 0.531] = $20,440

Processing equipment - cleaner jigs (pg.____):
   Two @ 5 yd^3/h

   Base cost: $Y_C = 6,403.82(5)^{0.595} = \$16,685$

       Equipment price   = $16,685 X 0.62 X 1.005 = $10,396
       Installation labor   = $16,685 X 0.24 X 1.025 =   4,105
       Construction materials = $16,685 X 0.14 X 1.015 =   2,370

Cleaner Jigs Capital Cost =
   [($10,396 + $4,105 + $2,370) X 2] = $33,742

118

Capital Costs

__Processing equipment - final jig (p.____):__
  0.2 yd^3/h

Base cost: $Y_C = 6,403.82(0.2)^{0.595} = \$2,458$

     Equipment price $= \$2,458 \times 0.62 \times 1.005 = \$1,532$
     Installation labor $= \$2,458 \times 0.24 \times 1.025 = \quad\$605$
     Construction materials $= \$2,458 \times 0.14 \times 1.015 = \quad\$349$

Final Jig Capital Cost =
  ($1,532 + $605 + $349) = $\underline{\$2,486}$

__Processing equipment - sluice (p.____):__
  50 yd^3/h

Base cost: $Y_C = 113.57(50)^{0.567} = \$1,044$

     Construction labor $= \$1,044 \times 0.61 \times 1.025 = \$653$
     Construction materials $= \$1,044 \times 0.39 \times 1.015 = \$413$

Sluice capital cost =
  ($653 + $413) = $\underline{\$1,066}$

__Processing equipment - sluice (p.____):__
  20 yd^3/h

Base cost: $Y_C = 113.57(20)^{0.567} = \$621$

     Construction labor $= \$621 \times 0.61 \times 1.025 = \$388$
     Construction materials $= \$621 \times 0.39 \times 1.015 = \$246$

Sluice capital cost =
  ($388 + $246) = $\underline{\$634}$

__Processing equipment - trommel (p.____):__
  100 LCY/h

Base cost: $Y_C = 7,176.21(100)^{0.559} = \$94,166$

     Equipment price $= \$94,166 \times 0.64 \times 1.005 = \$60,568$
     Installation labor $= \$94,166 \times 0.26 \times 1.025 = \$25,095$
     Construction materials $= \$94,166 \times 0.10 \times 1.015 = \quad\$9,558$

Trommel Capital Cost =
  ($60,568 + $25,095 + $9,558) = $\underline{\$95,221}$

Capital Costs

Supplemental - main building (p.   ):
    1,680 ft^2
    Cement floor
    Plumbing added

Base cost: $Y_C = 34.09(1,680)^{0.907} = \$28,707$

    Equipment   = $\$28,707 \times 0.25 \times 1.005 = \$7,213$
    Construction labor = $\$28,707 \times 0.34 \times 1.025 = \$10,004$
    Construction materials = $\$28,707 \times 0.41 \times 1.015 = \$11,946$

    Cement floor factor: $F_C = 1.035(1,680)^{0.008} = 1.098$
    Plumbing factor: $F_G = 1.013(1,680)^{0.002} = 1.028$

Main Building Capital Cost =
    $[(\$7,213 + \$10,004 + \$11,946) \times 1.098 \times 1.028] =$ $\underline{\$32,918}$

Supplemental - sheds (p.   ):
    Two @ 216 ft^2

Base cost: $Y_C = 34.09(216)^{0.907} = \$4,467$

    Equipment   = $\$4,467 \times 0.25 \times 1.005 = \$1,122$
    Construction labor = $\$4,467 \times 0.34 \times 1.025 = \$1,557$
    Construction materials = $\$4,467 \times 0.41 \times 1.015 = \$1,859$

Shed Capital Costs =
    $[(\$1,122 + \$1,557 + \$1,859) \times 2] =$ $\underline{\$9,076}$

Supplemental - employee housing (p.   ):
    100-LCY/h pay gravel
    250-LCY/h overburden
    350-LCY/h total
    Used trailers

Base cost: $Y_C = 7,002.51(350)^{0.418} = \$81,035$

    Equipment   = $\$81,035 \times 0.90 \times 1.005 = \$73,296$
    Construction labor = $\$81,035 \times 0.07 \times 1.025 = \$5,814$
    Construction materials = $\$81,035 \times 0.03 \times 1.015 = \$2,468$

    Used trailer factor: $F_U = 0.631$

Employee Housing Capital Cost =
    $[(\$73,296 + \$5,814 + \$2,468) \times 0.631] =$ $\underline{\$51,476}$

Capital Costs

Supplemental - generators (p.   ):
100-LCY/h mill feed

Base cost: $Y_C = 1,382.65(100)^{0.604} = \$22,321$

    Equipment $= \$22,321 \times 0.75 \times 1.005 = \$16,824$
    Construction labor $= \$22,321 \times 0.19 \times 1.025 = \$4,347$
    Construction materials $= \$22,321 \times 0.06 \times 1.015 = \$1,359$

Generator Capital Cost =
    $(\$16,824 + \$4,347 + \$1,359) =$ $\underline{\$22,530}$

Supplemental - pumps (p.   ):
100-LCY/h mill feed
80-ft head

Water consumption (p.   ) $= 94.089(100)^{0.546} = 1,163$ gpm

Base cost: $Y_C = 63.909(1163)^{0.618} = \$5,0130$

    Equipment $= \$5,013 \times 0.70 \times 1.005 = \$3,527$
    Installation labor $= \$5,013 \times 0.08 \times 1.025 = \$411$
    Construction materials $= \$5,013 \times 0.22 \times 1.015 = \$1,120$

Head factor: $F_H = 0.125(80)^{0.637} = 2.038$

Pump Capital Cost =
    $[(\$3,527 + \$411 + \$1,120) \times 2.038] =$ $\underline{\$10,308}$

Supplemental - settling ponds (p.   ):
1163 gpm

Base cost: $Y_C = 3.982(1163)^{0.952} = \$3,300$

    Equipment $= \$3,300 \times 0.75 \times 1.025 = \$2,537$
    Construction labor $= \$3,300 \times 0.25 \times 1.005 = \$829$

Settling Pond Capital Cost =
    $(\$2,537 + \$829) =$ $\underline{\$3,366}$

121

TABLE A-1. - Capital cost summary form

Item	Cost
Exploration:	
Method I cost..	$
Method II cost...	94,485
Development:	
Access roads...	88,180
Clearing...	9,725
Overburden Removal:	
Bulldozers...	
Draglines..	
Front-end loaders..	
Rear-dump trucks...	
Scrapers...	12,077
Mine Equipment:	
Backhoes...	266,792
Bulldozers...	69,022
Draglines..	
Front-end loaders..	272,207
Rear-dump trucks...	
Scrapers...	200,817
Processing Equipment:	
Conveyors..	16,115
Feed hoppers...	4,022
Jig concentrators..	56,668
Sluice...	1,700
Spiral concentrators...	
Table concentrators..	
Trommels...	95,221
Vibrating screens..	
Supplemental:	
Buildings..	41,994
Camp...	51,476
Generators...	22,530
Pumps..	10,308
Settling ponds...	3,366
Subtotal...	1,316,705
Contingency (10%)...	131,671
Total capital cost...	1,448,376

Operating Costs

Overburden removal - scrapers (p. ___):
    250 LCY/h
    3,000-ft average haul distance
    +8% average haul gradient plus rolling resistance
    Used equipment

Equipment: $Y_E = 0.325(250)^{-0.210} = \$0.102/LCY$

Parts	$= \$0.102 \times 0.18 \times 1.005 = \$0.018$
Fuel and lube	$= \$0.102 \times 0.48 \times 0.991 = \$0.049$
Tires	$= \$0.102 \times 0.34 \times 0.939 = \underline{\$0.033}$
	$\$0.100$

Labor: $Y_L = 12.01(250)^{-0.930} = \$0.071/LCY$

    Labor $= \$0.071 \times 1.00 \times 1.025 = \$0.073$

Distance factor:	$F_D = 0.01947(3,000)^{0.577}$	$=$	1.975
Gradient factor:	$F_G = 0.776e^{[0.047(8)]}$	$=$	1.130
Used equipment factor:	$U_E = 1.096(250)^{-0.006}$	$=$	1.060
	$U_L = 0.845(250)^{0.034}$	$=$	1.019

Overburden Removal Cost =
    $[(0.100 \times 1.060) + (0.073 \times 1.019)] \times 1.975 \times 1.130 = \$0.403/LCY$

Annual Scraper Operating Cost
    $\$0.403/LCY \times 375,000$ LCY/a = $151,125

Mining - backhoes (p. ___):
    Pay gravel excavation
    100 LCY/h
    80% maximum digging depth
    Medium-hard digging difficulty

Equipment: $Y_E = 8.360(100)^{-1.019} = \$0.077/LCY$

Parts	$= \$0.077 \times 0.38 \times 1.005 = \$0.029$
Fuel and lube	$= \$0.077 \times 0.62 \times 0.991 = \underline{\$0.047}$
	$\$0.076$

Labor: $Y_L = 17.53(100)^{-1.009} = \$0.168/LCY$

    Labor $= \$0.168 \times 1.00 \times 1.025 = \$0.172$

Digging depth factor,	$F_D = 0.09194(80)^{0.608}$	$=$	1.320
Digging difficulty factor, F_H		$=$	1.500

Backhoe Mining Cost =
    $[(0.076 + 0.172)] \times 1.320 \times 1.500 = \$0.491/LCY$

Annual Backhoe Operating Cost
    $\$0.491/LCY \times 150,000$ LCY/a = $73,650

Operating Costs

Mining - front-end loaders (p.   ):

    Pay gravel haulage
    100-LCY/h total
    Two 50-LCY/h loaders
    800-ft average haul distance
    +6% average haul gradient plus rolling resistance

Equipment: $Y_E = 0.407(50)^{-0.225} = \$0.169/LCY$

    Parts $= \$0.169 \times 0.22 \times 1.005 = \$0.037$
    Fuel and lube $= \$0.169 \times 0.46 \times 0.991 = \$0.077$
    Tires $= \$0.102 \times 0.32 \times 0.939 = \underline{\$0.051}$
                                                    $\$0.165$

Labor: $Y_L = 13.07(50)^{-0.936} = \$0.336/LCY$

    Labor $= \$0.336 \times 1.00 \times 1.025 = \$0.344$

Distance factor: $F_D = 0.023(800)^{0.616}$ $= 1.413$
Gradient factor: $F_G = 0.877e^{[0.046(6)]}$ $= 1.156$

Pay Gravel Transportation Cost =
    $(0.165 + 0.344) \times 1.413 \times 1.156 = \$0.831/LCY$

Annual Front-end loader Operating Cost
    $\$0.831/LCY \times 150,000\ LCY/y =$ $\underline{\$124,650}$

Processing - conveyors (p.   ):
    70 yd^3/h

Equipment: $Y_E = 0.218(70)^{-0.561} = \$0.020/yd^3$

    Parts $= \$0.020 \times 0.72 \times 1.005 = \$0.014$
    Electricity $= \$0.020 \times 0.24 \times 1.029 = \$0.005$
    Lube $= \$0.020 \times 0.04 \times 0.991 = \underline{\$0.001}$
                                                    $\$0.020$

Labor: $Y_L = 0.250(70)^{-0.702} = \$0.013/yd^3$

    Labor $= \$0.013 \times 1.00 \times 1.025 = \$0.013$

Conveyor Operating Cost =
    $(0.020 + 0.013) = \$0.033/yd^3$

Annual Conveyor Operating Cost
    $\$0.033/yd^3 \times 105,000\ yd^3/y =$ $\underline{\$3,465}$

Operating Costs

Processing - feed hoppers (p. ___):
    100-LCY/h total

    Equipment: $Y_E = 0.033(100)^{-0.344} = \$0.007/LCY$

        Parts   = \$0.007 X 0.88 X 1.005 = \$0.006
        Electricity   = \$0.007 X 0.06 X 1.029 = \$0.0004
        Lube   = \$0.007 X 0.06 X 0.991 = \$0.0004
                                                    \$0.007

    Labor: $Y_L = 0.017(100)^{-0.295} = \$0.004/LCY$

        Labor   = \$0.004 X 1.00 X 1.025 = \$0.004

Feed Hopper Operating Cost =
    (0.007 + 0.004) = \$0.011/LCY

Annual Feed Hopper Operating Cost
    \$0.011/LCY X 150,000 LCY/a = $\underline{\$1,650}$

Processing - rougher jig (p. ___):
    20 yd³/h

    Equipment: $Y_E = 0.113(20)^{-0.328} = \$0.042/yd^3$

        Parts   = \$0.042 X 0.40 X 1.005 = \$0.017
        Electricity   = \$0.042 X 0.34 X 1.029 = \$0.015
        Lube   = \$0.042 X 0.26 X 0.991 = \$0.011
                                                    \$0.043

    Supplies: $Y_S = 0.002(20)^{-0.184} = \$0.001/yd^3$

        Industrial materials = \$0.001 X 1.00 X 1.003 = \$0.001

    Labor: $Y_L = 3.508(20)^{-1.268} = \$0.079/yd^3$

        Labor   = \$0.079 X 1.00 X 1.025 = \$0.081

    Rougher service factor: $F_H = 0.344$

Rougher Jig Operating Cost =
    (0.043 + 0.001 + 0.081) X 0.344 = \$0.043/yd³

Annual Rougher Jig Operating Cost
    \$0.043/yd³ X 30,000 yd³/a = $\underline{\$1,290}$

Operating Costs

Processing - cleaner jigs (p.____):
Two @ 5 yd^3/h

Equipment: $Y_E = 0.113(5)^{-0.328} = \$0.067/yd^3$

Parts $= \$0.067 \times 0.40 \times 1.005 = \$0.027$
Electricity $= \$0.067 \times 0.34 \times 1.029 = \$0.023$
Lube $= \$0.067 \times 0.26 \times 0.991 = \underline{\$0.017}$
                                                  $\$0.067$

Supplies: $Y_S = 0.002(5)^{-0.184} = \$0.001/yd^3$

Industrial materials $= \$0.001 \times 1.00 \times 1.003 = \$0.001$

Labor: $Y_L = 3.508(5)^{-1.268} = \$0.456/yd^3$

Labor $= \$0.456 \times 1.00 \times 1.025 = \$0.467$

Rougher Jig Operating Cost =
   $(0.067 + 0.001 + 0.467) = \$0.535/yd^3$

Annual Rougher Jig Operating Cost
   $\$0.535/yd^3 \times 15,000 \ yd^3/a =$ $\underline{\$8,025}$

Processing - final jig (p.____):
0.2 yd^3/h

Equipment: $Y_E = 0.113(0.2)^{-0.328} = \$0.192/yd^3$

Parts $= \$0.192 \times 0.40 \times 1.005 = \$0.077$
Electricity $= \$0.192 \times 0.34 \times 1.029 = \$0.067$
Lube $= \$0.192 \times 0.26 \times 0.991 = \underline{\$0.049}$
                                                  $\$0.193$

Supplies: $Y_S = 0.002(0.2)^{-0.184} = \$0.003/yd^3$

Industrial materials $= \$0.003 \times 1.00 \times 1.003 = \$0.003$

Labor: $Y_L = 3.508(0.2)^{-1.268} = \$26.999/yd^3$

Labor $= \$26.999 \times 1.00 \times 1.025 = \$27.674$

Final Jig Operating Cost =
   $(0.193 + 0.003 + 27.674) = \$27.870/yd^3$

Annual Final Jig Operating Cost
   $\$27.870/yd^3 \times 300 \ yd^3/a =$ $\underline{\$8,361}$

Operating Costs

Processing - sluices (p.   ):
  50 yd^3/h

  Labor: $Y_L = 0.377(50)^{-0.636} = \$0.031/yd^3$

  Labor $= \$0.031 \times 1.00 \times 1.025 = \$0.032$

Sluice Operating Cost =
  $\$0.032/yd^3$

Annual Sluice Operating Cost
  $\$0.032/yd^3 \times 75,000 \ yd^3/a =$ $\underline{\$2,400}$

Processing - Sluices (p.   ):
  20 yd^3/h

  Labor: $Y_L = 0.377(20)^{-0.636} = \$0.056/yd^3$

  Labor $= \$0.056 \times 1.00 \times 1.025 = \$0.057$

Sluice Operating Cost =
  $\$0.057/yd^3$

Annual Sluice Operating Cost
  $\$0.057/yd^3 \times 30,000 \ yd^3/a =$ $\underline{\$1,710}$

Processing - Tailings placement - bulldozers (p.   ):
  100-LCY/h total
  400-ft average haul distance
  Minus 8% average haul gradient

  Equipment: $Y_E = 0.993(100)^{-0.430} = \$0.137/LCY$

    Parts $= \$0.137 \times 0.47 \times 1.005 = \$0.065$
    Fuel and lube $= \$0.137 \times 0.53 \times 0.991 = \underline{\$0.072}$
                                                        $\$0.137$

  Labor: $Y_L = 14.01(100)^{-0.945} = \$0.180/LCY$

    Labor $= \$0.180 \times 1.00 \times 1.025 = \$0.185$

  Distance factor: $F_D = 0.00581(400)^{0.904}$ $=$ 1.307
  Gradient factor: $F_G = 1.041e^{[0.015(-8)]}$ $=$ 0.923
  Used equipment factor: $U_E = 1.206(100)^{-0.013}$ $=$ 1.136
                         $U_L = 0.967(100)^{0.015}$ $=$ 1.036

Tailings Placement Cost =
  $[(0.137 \times 1.136) + (0.185 \times 1.036)] \times 1.307 \times 0.923 = \$0.419/LCY$

Annual Bulldozer Operating Cost
  $\$0.419/LCY \times 150,000 \ LCY/a =$ $\underline{\$62,850}$

Operating Costs

Processing - trommels (p. ___):
  100 LCY/h

  Equipment: $Y_E = 0.217(100)^{-0.403} = \$0.034/LCY$

  Parts $= \$0.034 \times 0.63 \times 1.005 = \$0.022$
  Electricity $= \$0.034 \times 0.26 \times 1.029 = \$0.009$
  Lube $= \$0.034 \times 0.11 \times 0.991 = \underline{\$0.004}$
  $ \$0.035$

  Labor: $Y_L = 0.129(100)^{-0.429} = \$0.018/LCY$

  Labor $= \$0.018 \times 1.00 \times 1.025 = \$0.018$

Trommel Operating Cost =
    $(\$0.035 + \$0.018) = \$0.053/LCY$

Annual Trommel Operating Cost
    $\$0.053/LCY \times 150,000 \ LCY/a =$ $\underline{\$7,950}$

Supplemental - housing (p. ___):
  100-LCY/h pay gravel
  250-LCY/h overburden
  350-LCY/h total

  Supplies: $Y_S = 1.445(350)^{-0.583} = \$0.047/LCY$

  Fuel $= \$0.047 \times 0.05 \times 0.991 = \$0.002$
  Industrial materials $= \$0.047 \times 0.95 \times 1.003 = \underline{\$0.045}$
  $ \$0.047$

Housing Operating Cost =
    $\$0.047/LCY$

Annual Housing Operating Cost
    $\$0.047/LCY \times 525,000 \ LCY/a =$ $\underline{\$24,675}$

128

Operating Costs

100-LCY/h mill feed

Equipment: $Y_E = 0.142(100)^{0.004} = \$0.145/LCY$

      Fuel $= \$0.145 \times 0.53 \times 0.991 = \$0.076$
      Parts $= \$0.145 \times 0.47 \times 1.005 = \underline{\$0.068}$
                                             $\$0.144$

Labor: $Y_L = 2.673(100)^{-0.524} = \$0.239/LCY$

   Labor $= \$0.239 \times 1.00 \times 1.025 = \$0.245$

Lost Time and General Service Cost =
   ($\$0.144 + \$0.245$) = $\$0.389/LCY$

Annual Lost Time and General Service Cost =
   $\$0.389/LCY \times 675,000$ LCY/a =   <u>$262,575</u>

100-LCY/h mill feed
1,163 gpm
80-ft head

Equipment: $Y_E = 0.007(1163)^{0.713} = \$1.074/h$

   Fuel and lube $= \$1.074 \times 0.59 \times 0.991 = \$0.628$
   Parts $= \$1.074 \times 0.41 \times 1.005 = \underline{\$0.443}$
                                         $\$1.071$

Labor: $Y_L = 0.004(1163)^{0.867} = \$1.819/h$

   Labor $= \$1.819 \times 1.00 \times 1.025 = \$1.864$

Head factor: $H_e = 0.091(80)^{0.735} = 2.279$

Pump Operating Cost = $H_1 = 0.054(80)^{0.893} = 2.739$

   [($\$1.071 \times 2.279$) + ($\$1.864 \times 2.739$)] = $\$7.546/h$

Annual Pump Operating Cost =
   $\$7.546/h \times 1,500h/a$ =   <u>$11,319</u>

TABLE A-2. - Operating cost summary form

Item	Cost/a
Overburden Removal:	
Bulldozers.. $	
Draglines...	
Front-end loaders...	
Rear-dump trucks..	
Scrapers..	151,125
Mining:	
Backhoes..	73,650
Bulldozers..	
Draglines...	
Front-end loaders...	124,650
Rear-dump trucks..	
Scrapers..	
Processing:	
Conveyors...	3,465
Feed hoppers..	1,650
Jig concentrators...	17,676
Sluice..	4,110
Spiral concentrators..	
Table concentrators...	
Tailings removal..	66,900
Trommels..	7,950
Vibrating screens...	
Supplemental:	
Camp..	24,675
Lost time and general services.............................	262,575
Pumps...	4,403
Subtotal..	742,829
Contingency (10%)..	74,283
Total..	817,112

Cost per cubic yard pay gravel = Total cost per cubic yard
pay gravel mined per year

$817,112/150,000 LCY/a = $5.45/LCY.

Final cost per cubic yard pay gravel........................... $5.45